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Physiological and toxicological studies on insects. Part I. Respiratory responses of adult orthoptera to certain gases. Part II. Toxicity of petroleum oil mixed with certain chemical compounds to larvae of Carpocapsa pomonella linne

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PHYSIOLOGICAL AND TOXICOLOGICAL STUDIES ON INSECTS

Part I. Respiratory Responses of Adult Orthoptera to Certain Gases.

Part II. Toxicity of Petroleum Oil Mixed with Certain Chemical Compounds to Larvae of *Carpocapsa pomonella* Linne.

By

Edward Rawson McGovran

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Respiratory Responses of Adult Orthoptera to Certain Gases

INTRODUCTION

The change in the volume of air that enters the tracheal system of an insect when it is exposed to toxic gases might well be considered in fumigation and in many spraying and dusting operations.

The oxygen consumption and carbon dioxide production of insects under varying conditions have often been investigated. However, these phenomena may, under certain conditions, be quite independent of the total volume of air taken into the tracheal system. In the case of some toxic gases the lethal effect may not be due to any interference with respiration directly but rather it may effect respiration only as a result of the destruction of the tissue. In such a case it would be desirable to know not only the changes in oxygen consumption and carbon dioxide production but also any changes in the total volume of air that passed into the tracheal system. If air permeated with a toxic gas is excluded from the tracheal system of an insect that gas would probably appear much less toxic than another gas of equal toxicity which stimulated the movement of air into the tracheal system.

In order to determine the effect of certain gases on the amount of air taken into the tracheal system a method

of measuring the tracheal ventilation was devised, and the effect of certain gases was studied.

The method is adapted to the study of the effect of various gases on the rate and amount of air movement into and out of the tracheal system. It may also be used to study the effect on the insect of passing various gases through the tracheal system and also to study the gain or loss of the constituents in a gas mixture which has passed through the tracheal system.

REVIEW OF LITERATURE

The effect of gases on the respiratory movements of insects was studied by Walling (1906). She observed that an atmosphere of CO_2 stopped the respiratory movements of grasshoppers, but that the insects recovered if placed in air after as long as two days' confinement in the gas. The respiratory movements of Dixippus morosus were observed by Buddenbrock and Rohr (1922). They found that the rate increased irregularly at various concentrations of CO_2 up to about thirty percent. Hazelhoff (1928) in tests with resting Periplaneta americana discovered that two or three per cent CO_2 opened the spiracular valves, and seven per cent or ten per cent CO_2 initiated respiratory movements. In the work of Brinley and Baker (1927) it is stated that methyl acetate will keep the spiracles of Melanoplus differentialis open in an atmosphere of HON. In studies with May beetles, Demoll (1927) reports that they were killed sooner when the head and thorax were exposed to chlorine than when only the abdomen was exposed.

The inhalation and exhalation of air by the respiratory movements of insects have been studied by a number of workers. According to Krogh (1920) a Dytiscus larva exhaled about two-thirds of the air in the large

longitudinal "respiratory" tracheae at each exhalation. Lee's (1925) experiments show that grasshoppers inhaled air normally through the first four pairs of spiracles, two pairs on the thorax and the first two pairs on the abdomen, and used the remaining spiracles on the abdomen in exhalation. McArthur (1929) observed that while normally grasshoppers breathed in the manner described above, it was possible for a grasshopper to exist for comparatively long periods of time with but a single pair of spiracles open. Stahn (1928) measured the volume of air exhaled by a single breathing movement of Dixippus morosus and observed that it varied between 0.15 c.mm. and 2.00 c.mm. Many other workers have investigated the problem of the mechanical ventilation of the tracheae and air sacs in insects.

MATERIALS AND METHODS

The apparatus as illustrated in Figure I consists of two closed chambers, A and B, which are connected by a tube y, into which the insect is sealed so that any air passing from one chamber to the other must pass through the tracheal system of the insect. The horizontal capillary glass tubes, A' and B', attached to each chamber, are each closed by a column of water about two or three centimeters long. These columns of water are free to move in either direction in the tubes. Metric rulers are attached to capillaries A' and B' to facilitate the measurement of the movement of the water columns. By the use of a manometer it was determined that if the capillaries used were about thirty centimeters long, clean and moist, and the water column near the center, an increase or decrease of one ten-thousandth (1/10,000) of an atmosphere in the pressure within the chamber would initiate a slow movement of the water column in the capillary tube. Rapid movements such as often occur during the most active respiratory movements of a grasshopper require a change in pressure of about one five-thousandth (1/5,000) of an atmosphere. With a capillary tube of between one and two millimeters bore a change in the volume

of the contents of either side of the apparatus of one cubic millimeter can be observed. Further, it is possible with this apparatus to maintain the air pressure in each of the two chambers in contact with the insect to within one ten-thousandth of the pressure of the surrounding atmosphere during any changes in the volume of air in either or both chambers within the limit of the capacity of the moist portion of the capillary tube and the volume of the pipette, a or b, attached to the chamber. Each of these pipettes is connected by a rubber tube to a reservoir, a' or b', containing water. These reservoirs open to the atmosphere by a long glass tube and are held in place by screw eyes driven into the side of the rack as shown in the figure. They can be raised or lowered by turning the handles, H. If the handle connected with reservoir a' by a cord is turned so that the reservoir is raised the water will flow from it into pipette a through the rubber tube connecting them. In this manner the total volume of air the A side of the apparatus can contain is decreased. If the reservoir is lowered, the water will flow into it from pipette a and the volume of air the A side of the apparatus can contain is increased. By repeated adjustment of the water level in pipette a so that the water column is kept about the center of the capillary tube A' a large change in volume in chamber

A can be permitted without an increase or decrease in the pressure in the chamber of more than one ten-thousandth (1/10,000) of an atmosphere. The same procedure can be followed with the B side of the apparatus. By the selection of a suitable pipette a test of any duration can be obtained; however, it is desirable to use a pipette of as small diameter as possible as this permits more accurate readings.

A short piece of glass tube, x, about five or six centimeters long that will just slip inside the tube, y, on the part of chamber B that extends into chamber A is used in sealing the insect into the passage between the chambers. One end of this tube, x, is heated and shaped so that it will fit fairly snugly (within about one millimeter on all sides) the body of the insect at the juncture of the thorax and abdomen. The tube that has once been properly shaped may be used repeatedly for insects of the same size and shape.

Each chamber is provided with two glass stop-cocks which were used to introduce gases and liquids into the chambers or to make the initial adjustment of the volume of air enclosed within the apparatus at the beginning of a test.

The rack R upon which the apparatus was mounted consisted of two wooden frames held together by an iron rod I and three hooks, h. The iron rod I was slipped through

both parts of the rack allowing them to be moved separately so that after an insect was placed in tube y the two sides of the rack with the apparatus attached could be moved together to close chamber A. Chamber A was closed by a ground glass joint where it slipped over the end of chamber B just back of tube y. Chamber B was closed by a ground glass stopper S. The rod I was used to suspend the apparatus in a water bath. The apparatus was held in place on the rack by heavy rubber bands. A rubber band was used to hold chambers A and B together and stopper S in place.

The small rubber bulbs A'' and B'' were used to adjust the water columns in the capillaries to the desired positions at the beginning of a test.

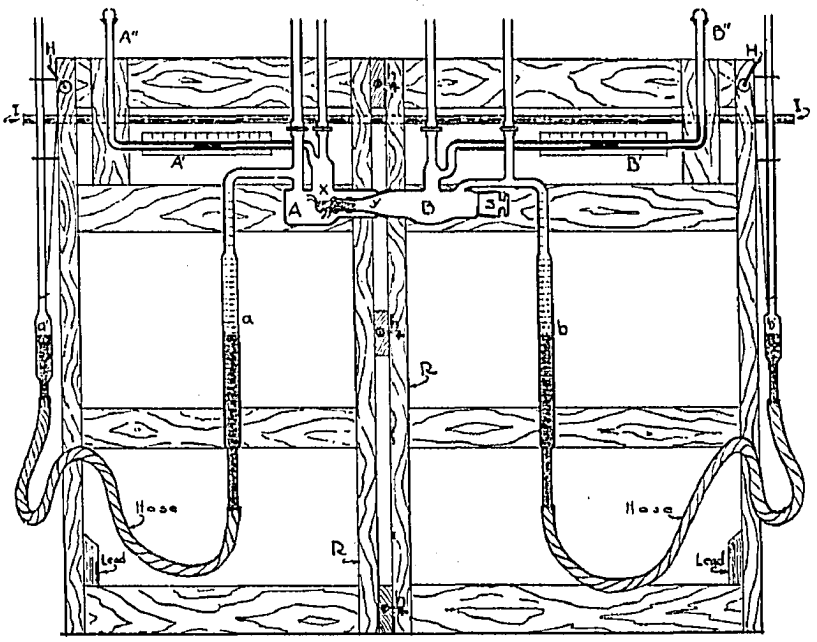

FIG. 1. An Apparatus for Measuring Tracheal Ventilation in Insects.

A.—A chamber that encloses the head and thorax of the insect. *B*.—A chamber that encloses the abdomen of the insect. *A'* and *B'*.—Capillary tubes closed by water columns. *A''* and *B''*.—Rubber bulbs. *a* and *b*.—25 cc. pipettes. *a'* and *b'*.—Adjustable reservoirs connected with pipettes *a* and *b*. *S*.—A ground glass stopper. *H*.—Handles used to adjust reservoirs *a'* and *b'*. *R*.—The two parts of the wooden rack the apparatus is mounted on. *I*.—An iron rod. *h*.—Hooks that hold the two parts of the rack together. *y*.—A tube that opens into chambers *A* and *B*. *x*.—A short piece of tube with the insect sealed inside it with beeswax and the tube, itself, sealed inside the tube *y* with vaseline.

Figure I

McGovran (1931)

Adult female grasshoppers, Chortophaga viridifasciata DeGeer, Arphia sulfurea Fab., Dissosteira carolina Linne, Melanoplus bivittatus Say, Melanoplus differentialis Thomas, and Hippicus, species undetermined, were used as experimental specimens. The abdomen of the insect was thrust into the tube x until the bases of the hind legs touched the end of the tube. The end of the tube that had been shaped to fit the insect's body was in this manner brought to encircle the insect at the juncture of the thorax and abdomen. The insect was sealed to the end of the tube by applying small drops of melted beeswax (about two milligrams) to the edge of the tube and allowing them to come in contact with the integument of the insect as they solidified. The insect was held securely in the end of the tube during this operation. The quantity of heat contained in such small drops of melted beeswax was not sufficient to injure the grasshopper appreciably. In this manner the posterior edge of the thorax and part of the anterior edge of the abdomen were sealed to the end of the glass tube x. The wax usually closed the tympanic spiracles. The tube with an insect sealed in the end was then filled with water and held with the insect downward to detect any leaks. If the seal was perfect, the water was removed from the tube and the insect allowed to remain quiet for, at least, forty-five

minutes. This period permitted the initial excitement of being confined in the tube to wear off. The short piece of tube x was then sealed with petroleum jelly inside the tube y. Chamber A was closed by moving the two parts of the apparatus together until an air tight seal was formed by the ground glass joint between chambers A and B.

The success of the test depended upon the insect being sealed perfectly into the tube that connected A and B. To test the seal the stop-cocks were closed on both the chambers and the pressure increased slightly in A. The pressure in either chamber could be increased by raising the level of the water in the pipette connected with it or decreased by lowering the level of the water in the pipette. If an increase in the pressure in A produced equal movements of the water columns in both capillaries A' and B' air was leaking from A into B around the insect. If the water column in capillary A' moved away from the chamber, but the one in capillary B' remained almost stationary the seal was perfect. A further check was made by increasing and decreasing the pressure in B by changing the water level in pipette b and observing the results. Care was taken not to apply too much pressure to A or B as this would have blown the water column out of the capillary tube.

When a perfect seal had been obtained the entire apparatus mounted on the rack was immersed in a water bath and allowed to remain fifteen minutes to assume the temperature of the bath. The water columns in the capillaries A' and B' and the level of the water in pipettes a and b were then adjusted to the desired positions with the stop-cocks on both chambers open. After the closure of all the stop-cocks the readings on the capillaries and pipettes were recorded and the test started. The closure of the stop-cocks enclosed a definite volume of air within the apparatus. This air could be moved from one chamber to the other by the respiratory movements of the insects, but the total volume of air within the apparatus remained constant unless more or less oxygen was used by the insect than the amount of carbon dioxide given off, or changes in atmospheric pressure occurred during the test. As the grasshopper breathed, the water column in capillary A' was observed to move toward chamber A and the water column in capillary B' was observed to move away from chamber B. When the water column approached the end of capillary A' the water level in pipette a was raised. This procedure forced some of the air out of pipette a into chamber A and capillary A' moving the water column away from the chamber. This operation was repeated each time the insect withdrew sufficient air from

chamber A so that the water column approached the end of capillary A' nearest chamber A. As the other water column approached the end of capillary B' farthest from chamber B the water level in pipette b was lowered. This procedure drew air into the pipette from chamber B and capillary B' so that the water column was moved toward the end of the capillary nearest chamber B. As soon as the insect had forced sufficient air into chamber B so that the water column approached the opposite end of the capillary the operation was repeated. In this manner it was possible to observe small changes (from one to four hundred cubic millimeters) in the volume of air in either chamber by noting the movements of the water columns in the capillaries. The total volume change (up to twenty-five cubic centimeters) in either chamber could be calculated from the difference between the positions of the water columns in the capillary tubes and the water levels in the pipettes from the beginning to the end of a test.

If the apparatus had not been in operation for 30 minutes or longer before a test was started it was found advisable to moisten the walls of the capillaries A' and B' by moving the water columns back and forth across the tube three or four times. The rubber bulbs A'' and B'' were used for this purpose. In the upper end of each bulb a small hole

that could be readily closed with a finger allowed air to be either forced into or drawn out of the capillary. In this manner the water columns could be easily moved back and forth in the tube and adjusted to any desired position. During a test the holes in the bulbs permitted the maintainence of atmospheric pressure within the capillary tubes. By clamping the walls of the rubber bulbs firmly together with a screw clamp it was possible to prevent the water columns from being forced out of the capillaries when the apparatus was moved or tipped.

In some tests a standard solution of $Ba(OH)_2$ was placed in each chamber to absorb the CO_2 evolved by the insect. The excess $Ba(OH)_2$ that remained at the end of the test was titrated through one of the stop-cocks with a standard solution of HCl. Phenolphthalein was used as the indicator.

Chambers A and B were rinsed with distilled water at the beginning of each test. The water was allowed to stand in the chambers for a short time to allow the air in the chambers to become nearly saturated with water vapor.

The investigations of toxic gases were made by introducing known volumes of a known concentration of the gas into chamber A through one of the stop-cocks. The study of the effect of nicotine was made by placing varying

amounts, as shown in the table, of one hundred per cent free nicotine in chamber A so that the grasshopper would inhale the vapor.

RESULTS

As previous workers have shown (Lee, 1925 and McArthur, 1929), air was principally inhaled into the thorax and principally exhaled from the abdomen. Four of the specimens studied normally breathed in the opposite direction as will be discussed later.

The first step in this study was to determine the normal amount of tracheal ventilation brought about by the respiratory movements of grasshoppers. The results of this study are given in Table I, page 22. The average amount of tracheal ventilation was 0.22 c.c. of air per minute per gram of body weight of the insect.

The average amount of air inhaled into the thorax at 28 degrees Centigrade at a single inhalation by Chortophaga viridifasciata was 0.006 c.c. based on 116 observations. The maximum amount inhaled at a single inhalation was 0.015 c.c. An average of 0.006 c.c. of air was exhaled from the abdomen at a single exhalation by these insects. The maximum amount of air exhaled at a single exhalation was 0.011 c.c.

When a standard solution of $Ba(OH)_2$ was placed in each chamber during 16 tests at 23° C. it was found that adult female Chortophaga viridifasciata exhaled an average

of about 20 per cent of the total CO_2 evolved from the head and thorax and about 80 per cent from the abdomen.

Table I

TRACHEAL VENTILATION OF Chortophaga viridifasciata DeG.

At 28° C.

Adult Females

Test No.	Barometric Pressure in mm. of Hg.	Duration of Test in Minutes	Total Amount of Tracheal Ventilation in c.c.	Tracheal Ventilation per Minute per Gram of Insect in c.c.
1	738.6	25	2.977	0.173
2	737.7	25	3.614	0.210
3	743.1	33	4.153	0.187
4	748.9	40	4.021	0.187
5	749.2	40	3.980	0.184
6	743.0	30	3.948	0.225
7	738.0	42	5.083	0.196
8	737.2	36	5.020	0.226
9	737.2	41	5.084	0.201
10	737.7	39	2.858	0.167
11	737.7	28	2.160	0.176
12	737.7	27	1.889	0.160
13	740.2	19	2.904	0.233
14	740.2	20	3.076	0.235
15	740.2	21	3.064	0.217
16	743.5	25	4.865	0.272
17	743.6	9	1.974	0.306
18	743.6	15	3.036	0.283
19	743.6	21	2.950	0.242
20	743.6	20	3.163	0.275
21	743.6	30	4.282	0.249
22	743.6	17	3.026	0.262
23	743.5	20	3.961	0.291
24	743.5	14	3.158	0.331
25	743.4	24	4.904	0.300
26	743.4	20	2.861	0.261
27	743.3	20	2.872	0.262
28	743.2	28	4.035	0.262
29	738.8	31	4.002	0.199
30	738.7	26	3.996	0.238
31	738.7	33	5.048	0.234
32	736.0	26	3.850	0.202
33	736.0	19	3.083	0.221
34	735.5	19	2.763	0.198
35	734.4	42	3.775	0.123
36	734.0	30	3.177	0.147
37	733.9	28	2.932	0.143
38	733.3	26	2.962	0.174
39	733.1	22	3.156	0.218
40	727.3	22	3.011	0.196
41	727.3	19	3.113	0.234
			Average	0.222± 0.043*

*Standard deviation Formula $\sigma = \sqrt{\frac{sd^2}{n-1}}$

In Table II, page 24, are found the results of exposing grasshoppers to fifteen per cent CO_2. This table shows that in about two-thirds of the tests the direction of the principal air movement through the tracheal system was reversed. That is, the air was inhaled principally into the abdomen and exhaled principally from the thorax after the insect had been confined in fifteen per cent CO_2 for a time. With the exception of four of the sixty-nine tests the rate of tracheal ventilation was increased. The maximum increase for any period was slightly more than twenty times the normal rate. The direction of the air movement through the tracheal system after the removal of the CO_2 was observed and found to be normal. The rate also returned to approximately normal in every instance.

Table II

EFFECT OF 15 PER CENT CO_2 ON THE TRACHEAL VENTILATION OF GRASSHOPPERS AT 28° C.

Test No.	Species	Wt. in Gms.	Duration of Normal Test in Min.	Ave. cc. Normal Tracheal Ventilation per Min. per Gm. of Insect	Min. Exposed in CO_2	Ave. cc. of Tracheal Ventilation per Gm. per Min. in 15% CO_2	Direction of Air Movement Through Tracheal System
1	C.v.[1]	0.75	108	0.06	17	0.01	Reversed
2	"	0.71	32	0.13	37	0.07	"
3	A.s.[2]	0.72	68	0.12	7	0.76	Normal*
4	C.v.	0.55	34	0.10	32	0.27	"
5	A.s.	0.88	93	0.07	24	0.24	Reversed
6	C.v.	0.62	30	0.01	21	0.02	Normal
7	A.s.	0.88	56	0.04	7	0.79	"
8	A.s.	1.03	50	0.02	12	0.42	"
9	A.s.	0.67	28	0.10	5	1.49	"
10	A.s.	0.59	46	0.18	6	1.41	"
11	A.s.	0.85	96	0.04	7	0.84	"
12	A.s.	0.85	79	0.05	6	0.97	"
13	D.c.[3]	1.22	26	0.25	3.5	1.17	Reversed
14	"**				3.5	1.16	"
15	"				3.5	1.19	"
16	"				5	0.82	"
17	"				6	0.68	"
18	D.c.	0.88	52	0.18	4	1.46	Normal
19	"				3	1.89	"
20	"				8	0.40	"
21	"				16	0.25	Reversed
22	"				10	0.51	"
23	"				10	0.57	"
24	D.c.	0.92	54	0.16	3	0.76	Normal
25	"				7	0.12	"
26	"				10	0.21	Reversed
27	"				9	0.34	"
28	"				5	0.47	"
29	"				8	0.26	"
30	D.c.	0.72	54	0.13	3	0.76	Normal
31	"				19	0.11	Reversed
32	"				6	0.46	"
33	"				8	0.66	"
34	D.c.	1.23	27	0.24	9	0.79	"
							"

29	"				8	0.26	
30	D.c.	0.72	54	0.13	3	0.76	Normal
31	"				19	0.11	Reversed
32	"				6	0.46	"
33	"				8	0.66	"
34	D.c.	1.23	27	0.24	9	0.79	"
35	"				4	0.72	"
36	D.c.	0.94	32	0.19	4	0.73	Normal
37	"				7	0.16	Reversed
38	"				5	0.46	"
39	"				5	0.62	"
40	"				5	0.85	"
41	"				7	0.63	"
42	D.c.	1.62	31	0.08	3	0.47	"
43	"				2	0.64	"
44	"				1.5	0.71	"
45	"				2	0.59	"
46	"				2	0.58	"
47	D.c.	1.12	24	0.18	6	0.31	"
48	"				3	0.60	"
49	"				3	0.57	"
50	"				4	0.45	"
51	"				4	0.42	"
52	D.c.	1.60	14	0.14	1	0.68	Normal
53	"				4	0.20	Reversed
54	"				2	0.64	"
55	"				2	0.63	"
56	"				7	0.61	"
57	D.c.	0.90	9	0.60	2	1.12	"
58	"				2.5	0.92	"
59	"				2.5	0.90	"
60	"				8	0.84	"

[1] Chortophaga viridifasciata De Geer

[2] Arphia sulphurea Fab.

[3] Dissosteira carolina Linne.

Note: The insects were all active at the end of the tests.

*Normal indicates that the air was inhaled into the thorax and exhaled from the abdomen.

**Ditto marks indicate that the same insect was used as in the preceeding test. Usually the tests were run in sequence without removing the insect from the apparatus.

The effect of one per cent CO_2 as recorded in Table III, page 26, was to slightly increase the rate of air movement in less than half of the tests. No instance of the reversal of the direction of air movement through the tracheal system was observed.

Table III

EFFECT OF 1 PER CENT CO_2 ON THE TRACHEAL VENTILATION OF *Dissosteira carolina* L. AT 28° C.

Test No.	Wt. in Grams	Duration of Normal Test in Min.	Average c.c. Normal Tracheal Ventilation per Min. per Gm. of Insect	Min. Exposed in CO_2	Average c.c. of Tracheal Ventilation per Gm. per Min. in 1% CO_2	Direction of Air Movement Through Tracheal System
1	1.40	22	0.26	4	0.35	Normal*
2	" **			3	0.49	"
3	"			3	0.71	"
4	"			2	0.69	"
5	"			2.5	0.58	"
6	"			3.5	0.39	"
7	0.68	43	0.08	7	0.23	"
8	"			25	0.06	"
9	"			12	0.12	"
10	"			5	0.20	"
11	0.98	14	0.22	3	0.32	"
12	"			5	0.21	"
13	"			5	0.22	"
14	"			6	0.18	"
15	"			11	0.16	"
16	1.76	37	0.15	8	0.13	"
17	"			9	0.13	"
18	"			5	0.14	"
19	"			8	0.12	"
20	"			4	0.17	"
21	"			4	0.14	"
22	1.03	10	0.69	8	0.28	"
23	"			3	0.52	"
24	"			6	0.17	"
25	"			6	0.32	"
26	"			9	0.24	"

Note: The insects were all active at the end of the tests.

* Normal indicates that the air was inhaled into the thorax and exhaled from the abdomen.

** Ditto marks indicate that the same insect was used as in the preceeding test. Usually the tests were run in sequence without removing the insect from the apparatus.

Sub-lethal doses of OS_2 (Tests 1-7, Table IV, page 28) all produced an increase in the rate of tracheal ventilation. Concentrations of OS_2 that rendered the insect motionless by the end of the series of tests in most instances produced a sudden rise in the rate of tracheal ventilation followed by a gradual fall as the insect became less and less active. The direction of air movement through the tracheal system was not reversed.

Table IV

EFFECT OF CS_2 ON TRACHEAL VENTILATION OF ADULT FEMALE GRASSHOPPERS

Arphia sulphurea Fab.

Test No.	Wt. of Insect in Gms.	Duration of Normal Test in Min.	C.C. of Normal Ventilation per Min. per Gm.	Percent CS_2 in Chamber Enclosing Thorax	Duration of Test in Min.	C.C. Ventilation per Min. per Gm. in CS_2	Direction of Air Movement Through Tracheal System	Condition of Insect at End of Test
1	0.83	57	0.10	1	21	0.12	Normal	Active
2	"				9	0.13	"	"
3	0.73	66	0.07	3	14	0.11	"	"
4	"				13	0.09	"	"
5	"				12	0.12	"	"
6	0.95	42	0.05	5	15	0.08	"	"
7	"				14	0.07	"	"
8	0.85	36	0.10	10	9	0.13	"	"
9	"				5	0.24	"	"
10	"				10	0.12	"	"
11	"				17	0.04	"	Motionless
12	0.81	39	0.09	10	5	0.20	"	Active
13	"				8	0.17	"	"
14	"				19	0.07	"	Motionless
15	1.01	32	0.12	10	12	0.09	"	Active
16	"				10	0.01	"	Motionless
17	0.94	61	0.05	8	9	0.13	"	Active
18	"				5	0.16	"	"
19	"				17	0.06	"	"
20	"				20	0.01	"	Motionless
21	1.08	42	0.07	8	8	0.21	"	Active
22	"				7	0.15	"	"
23	"				21	0.05	"	"
24	"				9	0.01	"	Motionless
25	0.99	52	0.06	8	11	0.09	"	Active
26	"				14	0.08	"	"
27	"				19	0.05	"	"
28	"				28	0.05	"	Motionless
29	0.86	42	0.09	8	7	0.13	"	Active
30	"				14	0.09	"	"
31	"				9	0.14	"	"
32	"				13	0.18	"	Motionless
33	0.81	119	0.01	8	23	0.05	"	Active
34	"				21	0.06	"	"

9	"				5	0.24	"	"
10	"				10	0.12	"	"
11	"				17	0.04	"	Motion-less
12	0.81	39	0.09	10	5	0.20	"	Active
13	"				8	0.17	"	"
14	"				19	0.07	"	Motion-less
15	1.01	32	0.12	10	12	0.09	"	Active
16	"				10	0.01	"	Motion-less
17	0.94	61	0.05	8	9	0.13	"	Active
18	"				5	0.16	"	"
19	"				17	0.06	"	"
20	"				20	0.01	"	Motion-less
21	1.08	42	0.07	8	8	0.21	"	Active
22	"				7	0.15	"	"
23	"				21	0.05	"	"
24	"				9	0.01	"	Motion-less
25	0.99	52	0.06	8	11	0.09	"	Active
26	"				14	0.08	"	"
27	"				19	0.05	"	"
28	"				28	0.05	"	Motion-less
29	0.86	42	0.09	8	7	0.13	"	Active
30	"				14	0.09	"	"
31	"				9	0.14	"	"
32	"				13	0.18	"	Motion-less
33	0.81	119	0.01	8	23	0.05	"	Active
34	"				21	0.06	"	"
35	"				80	0.02	"	Motion-less
36	0.73	67	0.08	8	17	0.06	"	Active
37	"				11	0.16	"	"
38	"				12	0.09	"	"
39	"				17	0.01	"	Motion-less
40	0.96	52	0.06	8	18	0.06	"	Active
41	"				19	0.07	"	"
42	"				10	0.08	"	"
43	"				24	0.04	"	Motion-less
44	0.84	32	0.07	8	7	0.16	"	Active
45	"				7	0.13	"	"
46	"				43	0.03	"	Motion-less

The effect of HCN as set forth in Table V, page 30, indicates that 0.2 per cent HCN caused a rapid decrease in the rate of tracheal ventilation as the insect was killed rapidly. One tenth per cent HCN sooner or later produced a rise in the rate of tracheal ventilation which was followed by a gradual fall as the insect was stupified by the gas.

Table V

EFFECT OF HCN ON THE TRACHEAL VENTILATION OF GRASSHOPPERS

AT 28° C.

Test No.	Species	Wt. in Gms.	Duration of Normal Test in Min.	C.C. Normal Tracheal Ventilation per Gm. per Min.	Per cent HCN in Chamber Enclosing Thorax	Min. in HCN	C.C. Tracheal Ventilation per Gm. per Min. in HCN	Direction of Air Movement Through Tracheal System	Condition of Insect at End of Test
1	D.c.[3]	0.90	26	0.12	0.2	4	0.28	Normal	Active
2	"					6	0.38	"	"
3	"					4	0.61	"	"
4	"					3	0.66	"	"
5	"					3	0.68	"	"
6	"					9	0.12	"	"
7	"					23	0100	"	"
8	"					10	0.17	"	Motionless
9	D.c.	1.42	8	0.56	0.2	3	0.24	"	Active
10	"					10	0.07	"	"
11	"					5	0.01	"	Motionless
12	D.c.	1.19	10	0.67	0.2	13	0.03	"	"
13	D.c.	0.90	54	0.12	0.2	3	0.32	"	Active
14	"					16	0.02	"	Motionless
15	D.c.	0.91	18	0.20	0.1	2	0.46	"	Active
16	"					5	0.27	"	"
17	"					14	0.01	"	Motionless
18	M.b.[4]	1.52	15	0.13	0.1	15	0.10	"	Active
19	"					16	0.05	"	"
20	"					3	0.16	"	"
21	"					4	0.34	"	"
22	"					4	0.37	"	"
23	"					6	0.22	"	"
24	M.b.	1.37	27	0.13	0.1	2	0.24	"	"
25	"					12	0.08	"	"
26	"					24	0.04	"	Motionless
27	M.d.[5]	0.79	37	0.11	0.1	21	0.00	"	"
28	"					10	0.13	"	Active
29	"					22	0.06	"	Motionless
30	M.b.	0.96	21	0.11	0.1	6	0.14	"	Active

6	"					23	0100	"	
7	"					10	0.17	"	Motion-less
8	D.c.	1.42	8	0.56	0.2	3	0.24	"	Active
9	"					10	0.07	"	"
10	"					5	0.01	"	Motion-less
11	D.c.	1.19	10	0.67	0.2	13	0.03	"	"
12	D.c.	0.90	54	0.12	0.2	3	0.32	"	Active
13	"					16	0.02	"	Motion-less
14	D.c.	0.91	18	0.20	0.1	2	0.46	"	Active
15	"					5	0.27	"	"
16	"					14	0.01	"	Motion-less
17	M.b.[4]	1.52	15	0.13	0.1	15	0.10	"	Active
18	"					16	0.05	"	"
19	"					3	0.16	"	"
20	"					4	0.34	"	"
21	"					4	0.37	"	"
22	"					6	0.22	"	"
23	M.b.	1.37	27	0.13	0.1	2	0.24	"	"
24	"					12	0.08	"	"
25	"					24	0.04	"	Motion-less
26	M.d.[5]	0.79	37	0.11	0.1	21	0.00	"	"
27	"					10	0.13	"	Active
28	"					22	0.06	"	Motion-less
29	M.b.	0.96	21	0.11	0.1	6	0.14	"	Active
30	"					30	0.04	"	Motion-less
31									

[3] Dissosteira carolina L.

[4] Melanoplus bivittatus Say.

[5] Melanoplus differentialis Thomas.

The nicotine vapor released from 100 per cent free nicotine (Table VI, page 32) did not in most cases render the grasshoppers inactive in the time they were exposed, but one insect died shortly after being removed from the apparatus. In most instances there was an increase in the rate of tracheal ventilation which was followed by a gradual fall in about half of the grasshoppers observed. In one instance there was a reversal of the direction of air movement.

Table VI

EFFECT OF NICOTINE ON THE TRACHEAL VENTILATION OF GRASSHOPPERS AT 28° C.

Test No.	Species	Wt. in Gms.	Duration of Normal Test in Min.	C.C. Normal Tracheal Ventilation per Min.	C.C. of Nicotine in Chamber A	Min. in Test	C.C. Ventilation per Min. with Nic. in Chamber A	Direction of Air Movement Through Tracheal System	Condition of Insect at End of Test
1	A.s.[1]	0.67	60	0.08	0.0006	44	0.11	Normal	Active
2	A.s.	0.59	40	0.08	0.01	33	0.09	"	"
3	C.v.[2]	0.52	70	0.08	0.1	20	0.09	"	"
4	"					33	0.07	Reversed	"
5	"					21	0.01	"	"
6	A.s.	0.97	25	0.09	0.2	8	0.13	Normal	"
7	"					8	0.12	"	"
8	"					11	0.09	"	"
9	"					14	0.07	"	"
10	"					12	0.11	"	"
11	"					11	0.10	"	"
12	"					7	0.13	"	"
13	"					8	0.14	"	"
14	"					17	0.11	"	"
15	"					18	0.11	"	Sluggish
16	H[3]	2.40	30	0.07	0.5	5	0.07	"	Active
17	"					5	0.07	"	"
18	"					6	0.07	"	"
19	"					7	0.07	"	"
20	"					5	0.08	"	"
21	"					5	0.07	"	"
22	"					6	0.07	"	"
23	"					6	0.07	"	"
24	"					11	0.08	"	"
25	"					5	0.10	"	"
26	"					5	0.07	"	"
27	"					7	0.08	"	"
28	"					5	0.07	"	"
29	"					7	0.06	"	"
30	"					11	0.07	"	"

9	"					12	0.11	"	"
10	"					11	0.10	"	"
11	"					7	0.13	"	"
12	"					8	0.14	"	"
13	"					17	0.11	"	"
14	"					18	0.11	"	Sluggish
15	"					5	0.07	"	Active
16	H[3]	2.40	30	0.07	0.5	5	0.07	"	"
17	"					6	0.07	"	"
18	"					7	0.07	"	"
19	"					5	0.08	"	"
20	"					5	0.07	"	"
21	"					6	0.07	"	"
22	"					6	0.07	"	"
23	"					11	0.08	"	"
24	"					5	0.10	"	"
25	"					5	0.07	"	"
26	"					7	0.08	"	"
27	"					5	0.07	"	"
28	"					7	0.06	"	"
29	"					11	0.07	"	"
30	"					6	0.07	"	"
31	"					7	0.07	"	"
32	"					11	0.04	"	"
33	"					19	0.06	"	"
34	A.s.	0.76	101	0.05	0.5	20	0.07	"	"
35	"					15	0.07	"	"
36	"					77	0.04	"	Motion-less
37	"					4	0.37	"	"
38	A.s.	0.80	37	0.14	0.5	15	0.07	"	Active
39	A.s.	0.80	68	0.05	0.5	20	0.05	"	"
40	"					25	0.05	"	"
41	"								

[1] Arphia sulphurea Fab.

[2] Chortophaga viridifasciata De Geer.

[3] Hippiscus, species undetermined.

DISCUSSION

The confinement of the insects in the manner described did not seem to injure them. One grasshopper which was allowed to remain sealed in the tube for 24 hours fed immediately after it was released. Grasshoppers that had been used as experimental animals have been observed to lay eggs which later hatched.

The apparatus as operated in these tests recorded only the movement of air completely through the tracheal system. In many of the tests, especially with 15 per cent CO_2, the insects inhaled and exhaled rapidly and deeply, but did not produce a correspondingly large movement of air into the thorax and out of the abdomen. This was most noticeable when the direction of air movement through the tracheal system was being reversed. First, the air movement in the normal direction would be reduced until it stopped entirely, but air was still rapidly inhaled and exhaled with each spiracle apparently performing equally as inhalatory and exhalatory orifices. After a short period of this type of breathing more air began to be exhaled from the thorax than was inhaled into the thorax, which was a reversal of the normal.

Four of the specimens studied normally inhaled principally into the abdomen and exhaled from the thorax. One of these was parasitized by three nearly full-grown larvae of Sarcophaga marginata Ald., Order Diptera, another was gravid and the two others appeared normal upon dissection.

SUMMARY

A method is described that can be used to measure the tracheal ventilation of grasshoppers. Chortophaga viridifasciata DeGeer, Arphia sulphurea Fab., Dissosteira carolina Linne, Melanoplus bivittatus Say, Melanoplus differentialis Thomas, and Hippiscus, species undetermined were the species studied.

The respiratory movements of the grasshoppers produced a streaming movement of air through the tracheal system. The air was inhaled principally into the thorax and exhaled principally from the abdomen.

Adult Chorotophaga viridifasciata females at 28° C. passed an average of 0.22 c.c. of air through their tracheal system per minute per gram of body weight with a minimum of 0.12 cc. and a maximum of 0.33 c.c.

Adult Chorotophaga viridifasciata females exhaled an average of 20 per cent of the total CO_2 evolved from the thorax and 80 per cent from the abdomen at 23° C. If it can be assumed that all the air exhaled contains the same percentage of CO_2, it is evident that only part (about 80 per cent) of the air movement within the tracheal system of these insects is a through movement in the direction given above.

In 93 per cent of the tests 15 per cent CO_2 produced an increase in the rate of tracheal ventilation. The maximum increase for any period was slightly more than 2000 per cent. Seventy-two per cent of the tests showed a reversal of the direction of air movement through the tracheal system.

One per cent CO_2 did not consistently increase the rate of tracheal ventilation nor reverse the direction of air movement through the tracheal system in a single instance.

Sub-lethal concentrations of CS_2 and nicotine vapor usually increased the rate of tracheal ventilation.

High concentrations (0.2 per cent) of HCN produced a rapid fall in the rate of tracheal ventilation.

Concentrations of CS_2 and HCN which killed the insect slowly produced an initial increase in the rate of tracheal ventilation which was followed by a decrease as the gas rendered the insect less and less active.

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Part II

Toxicity of Petroleum Oil Mixed with Certain Chemical Compounds to Larvae of *Carpocapsa pomonella* Linne.

INTRODUCTION

Lead arsenate has been used as a larvicide for codling moth (Carpocapsa pomonella Linne) since the beginning of the twentieth century. This insecticide has given the most widespread, constant and economical control of codling moth on apples of any of the materials that have been investigated for this purpose. Within the last few years, however, the degree of control obtained has not been satisfactory in all cases. In spite of higher concentrations of lead arsenate in the spray solution and of increases in the amount of spray applied to each tree, and in the number of applications, there has been an almost constant rise in the percentage of the apple crop that has been destroyed by this pest in certain sections of the United States. Various materials have been added to the lead arsenate sprays in an effort to improve their efficiency. "Wetters", "spreaders" and "stickers" of different types have been used with a moderate degree of success. One of these materials which has been widely employed is refined petroleum oil in the form of an emulsion. This material when applied alone has given a fair degree of control in moderate to light infestations. Much better control is obtained when mineral oil emulsion is mixed with lead arsenate. Not only does the arsenical adhere

to the fruit better, thus retarding its removal by the action of the weather, but the oil also acts as a very efficient ovicide.

Another serious objection that has been raised to the use of lead arsenate sprays in recent years is the toxicity of lead and arsenic to man and the higher animals. This has led to strict regulations as to the amount of lead and arsenical residue that may remain on the fruit when it reaches the market.

In view of these facts, an investigation was made of some of the available chemical compounds and mixtures to determine their toxicity to codling moth larvae when they were dispersed in refined petroleum oil.

REVIEW OF LITERATURE

The number of articles published on the use of lead arsenate for the control of codling moth has run into the thousands since this material was first prepared for use as an insecticide in 1892 (Fernald, 1898). It has been mixed with various materials which have improved the control in some instances. Newcomer and Yothers (1932) found that small quantities of casein caused lead arsenate to be somewhat more effective, but that larger amounts did not have this effect. They found calcium, tricalcium, aluminum, barium, ferric, zinc, copper, titanium, magnesium and manganese arsenate and calcium arsenite to be less effective than lead arsenate against the larvae of codling moth. Zinc arsenite was slightly more effective. They found one per cent crystal oil[1] to have practically no effect on the larvae and 2 per cent cyrstal oil to be about half as effective as lead arsenate in the proportion of 2 pounds to 100 gallons of water. They also report that nicotine sulfate, 1-800 or 1-1600 mixed with one per cent lubricating oil emulsion, gave good control. Further they state, "Poor results were obtained with crude dipyridyl sulfate and crude benzyl pyridine. Derris in the form tested was ineffective and pyrethrum extracts were effective for only

[1] Crystal oil- Volatility 0.84 per cent, Viscosity 122 sec., Specific Grabity 0.87, unsulfonated residue 95.2 per cent.

a short time after being applied." They also report that nicotine tannate gave some indications of satisfactory control.

McAllister and Van Leeuwen (1930) determined the toxicity of 284 materials to newly hatched codling moth larvae. At ten per cent concentration in talc dust, diphenylamine, 2-4 dinitrotoluene, 2-4 dinitrophenol, 3-5 dinitro-o-cresol, alpha naphthylamine and beta chloroethyl-p-toluene sulfonate almost equalled or exceeded the per cent efficiency of ten per cent acid lead arsenate in talc dust. They report the following materials to be 100 per cent effective when used as an undiluted dust: diazoaminobenzene, acetoacetanilide, dibromonaphthalene, nitronaphthylamine and veratrine alkaloid. Thioacetanilide, potassium methyl zanthate, alpha nitronaphthalene, 3-nitro-4-amino-toluene, alpha naphthylamine, meroury sulfocyanate, guanidine, thiocyanate, diphenylamine, 2-6 dinitrotoluene, 2-4 dinitroaniline, 2-4 dinitrotoluene and 2-4 dinitrochloro-benzene gave between 90 and 100 per cent efficiency when used as undiluted dusts. The following liquids, acid lead arsenate 4 pounds in 100 gallons of water, di-n-butyloyanamide, beta chloroethyl-p-toluene sulfonate, di-benzylamine, ethyl benzyl-o-toluidine, ethyl thiocyanate, methyl alpha naphthylamine and n-propyl-p-

toluene sulfonate, when used at 10 per cent in talc dust gave between 90 and 100 per cent efficiency.

Filmer (1931) reports that when a sufficient coating of nicotine tannate is maintained upon the foliage it controls codling moth as well as lead arsenate but that weathering removes 60 to 70 per cent of the nicotine tannate during the first ten days following its application.

Quaintance, A.L., et al (1931) reports that barium fluosilicate gave results equal to lead arsenate in two instances and poorer in two instances. Different brands of fluosilicates and synthetic cryolite failed to control codling moth in Missouri. Poor results were obtained with sodium fluosilicate and potassium fluoaluminate. Rotenone was reported effective immediately after application but rapidly lost its effectiveness.

Insecticides as applied to insects other than codling moth have been studied from the point of view of chemical structure, by a number of workers.

Cooper and Nuttall (1915) called attention to the possible development of insecticides from a study of the relation of chemical structure to toxicity to insects.

When used as stomach poisons Hargreaves (1924) reports ammonium-ortho-di-nitro-cresylate as the most toxic

to caterpillars of about 100 chemicals tested.

Moore and Campbell (1924) report copper cyanide and thiocyanate as being toxic to the Japanese beetle and the tent caterpillar respectively.

Brinley (1926) reports diphenylamino arsenious oxide as being about equal to lead arsenate in toxicity to the tent caterpillar.

Gimingham and Tattersfield (1928) found extracts of hariari and tephrosia to be very repellant to various chewing insects.

Campbell (1932) reports malachite green, safranin bluish, brilliant green and crystal violet as being toxic to silkworms.

Turner (1932) found cube' extract and rotenone in various dispersing agents to be effective as a contact insecticide against aphids. These preparations did not prove effective against insect eggs except in one instance. Rotenone in oil showed considerable toxicity to Colorado Potato Beetle (Leptinotarsa decemlineata Say) larvae but was inferior to lead arsenate at the concentrations tested. Rotenone deteriorated rapidly in the presence of soap and water but was apparently stable in water, or oil-soluble sulfonate, or oil emulsified with skimmed milk.

Contact insecticides were studied from the chemical standpoint by Cooper and Walling (1915). They found arsenic sulfide and nitrobenzene to be the most toxic of the chemicals they tested on blowfly larvae.

Richardson and Smith (1923) tested a number of aliphatic and aromatic carbon compounds on Aphis rumicis L. They state: "Chemical structure does not appear to be a dependable index to toxicity. Nevertheless it is probably the best empirical guide at present available for the study of contact insecticides."

Tattersfield and associates (1925), (1926) and (1927) have studied the toxicity of plant extracts and N-Heterocylic compounds to Aphis rumicis L.

Siegler and Popenoe (1925) found capric acid to be the most toxic of the fatty acids to aphids with a decrease as the number of carbon atoms increased or decreased.

These results were confirmed in general by Tattersfield and Gimingham (1927a). They also found formic acid to be more toxic than the acids with two, three and four carbon atoms.

Richardson and Smith (1926) found that crude dypyridyl oil prepared from pyridine and sodium was more

toxic to certain insects when used as a contact insecticide than nicotine.

Richardson and Shepard (1930) studied the toxicity of some nitrogenous organic compounds to Aphis rumicis L. and found metanicotine and nicotyrine were the only substances approaching nicotine in toxicity.

Smith, Richardson and Shepard (1930) studied the toxicity of twenty-five dipyridyl and related compounds to Aphis rumicis L. and found neonicotine to be the most toxic compound.

Of the more recent additions to our knowledge of chemical structure of insecticides, Vollmar (1931) gave a picture of pyrethrin I and II. However, the structure of these compounds was first worked out in 1924. LaForge and Haller (1932) gave the structural formula of rotenone.

Jones, et al (1933) found that lamp black reduced the loss in toxicity of rotenone when exposed to light and tested on mosquito larvae. Dihydrorotenone was more stable and slightly more toxic than rotenone.

Gimingham, Masse and Tattersfield (1926) found 3:5 dinitro-6-cresol to be quite toxic to insect eggs.

Wardle (1928) pages 181-186 gives a good summary of the work that has been done on the relation of chemical structure to toxicity of contact insecticides.

The use of materials of known chemical structure as fumigants was studied by Moore (1917). He concludes that boiling point and vapor pressures are more important than chemical structure.

Tattersfield and Roberts (1920) tested the vapor of organic compounds or wireworms. They found chemicals with boiling points between 170° and 217° C. are uncertain in their action and those boiling above 245° C. are non-toxic.

Neifert, Cook, Roark and Tonkin (1925) tested more than 100 organic chemicals as fumigants against weevils infesting stored grain. They found epichlorohydrin and phenylacetophenone to be the most toxic.

Cotton and Roark (1928) tested some alkyl and alkylene formates against rice weevil, Sitophilus oryza L. Methyl formate and allyl-formate were the most toxic.

Craig (1931) tested some nitrogen heterocyclic compounds against Tribolium confusum Duval. He found a-phenylpyrrolidine to rank next to nicotine in toxicity and pyridine to have the lowest toxicity.

O'Kane (1932) in a review of materials employed as insecticides before 1896 lists Paris green, lead arsenate, calcium polysulphides, kerosene emulsion, kerosene and alcohol extracts of pyrethrum, carbon disulfide and carbon disulfide emulsion, hydrocyanic acid gas, nicotine, mercuric

chloride, fish oil and oils such as those of petroleum. The group of plants having insecticidal properties and of which derris is a typical example had also been used. Dr. O'Kane discusses fluorine compounds, para-di-chlorobenzene, copper within the plant juices, and other plant extracts, for example the extract of Cracca commonly called the Devil's Shoestring as some of the new insecticides that have been discovered since that time.

He points out that perhaps the greatest advance has been the improvement in the methods of preparation and application of all these materials. Supplementing each others efforts, the chemist and entomologist have produced insecticides that are giving excellent control of many pests. The various studies of the physiological effects on the insect of these insecticides have made possible many of the present day improvements. With all the advances that have been made Dr. O'Kane calls attention to the fact that the need for continued effort is perhaps even greater now than formerly. He states that 62 per cent of the major insect pests are not as yet satisfactorily controlled.

MATERIALS AND METHODS

Small Ben Davis apples were cleaned of all spray residue and the cavities around the stem and calyx were sealed with paraffin. A paper clip attached by a string to a tag was thrust into the stem end of each apple before the paraffin was applied.

The apples were sprayed with impregnated white oil[1] with an atomizer operated by compressed air at 15 pounds pressure. A differential manometer was used to assure a uniform flow of air through the atomizer at all times. The apples were sprayed for 20 seconds. A volume of 1.18 c.c. of oil was delivered by the atomizer. The temperature ranged from 18° to 24° C. The apples were stored for 24 hours before they were infested. Ten newly hatched codling moth larvae were placed on each apple. The larvae were obtained by the method of Farrar and Flint (1930).

As soon as the larvae had been transferred to the apples, the apples were placed in a constant temperature unit at 26.7° C. and 50 per cent relative humidity for 24 hours. After this period, during which all the surviving codling moth larvae had entered the apples, the apples were stored in

(1) Petroleum oil- Specific Gravity 0.857, Viscosity 83 sec., Per cent Absorption by sulfuric acid 1, Per cent loss by evaporation, 0.

a greenhouse for five days. At the end of this period the number of stings and entries in each apple was recorded. If a larva had penetrated less than one-fourth of an inch into the apple, the injury was considered as a sting, if the live insect was not found. If the hole was more than one-fourth of an inch deep, or a live larva was found, the injury was counted as an entry.

The percentage controlled was calculated by the method suggested by the Insecticide and Fungicide Board of the United States Bureau of Entomology (Wardle, 1928, pages 145-146).

STATISTICAL INTERPRETATION OF RESULTS

The data recorded in Table VII through Table XXIII in this investigation were analyzed by the Significance of Difference of Means of Small Samples as described by Fisher (1932).

This analysis showed that in tests using only 30 larvae the variation due to chance was so great that the results could only be considered as indications of what might be expected from these mixtures. This fact, however, does not destroy the value of the data obtained from these short series, namely that the mixtures tested did not in most instances give satisfactory control of codling moth larvae.

In tests where 60 larvae were used to determine each mean a variation of an average of 2.0 entries per apple was found to be due to chance between 1 in 10 times and 1 in 20 times. That is, a variation of this magnitude would occur purely by chance in the same population between 1 to 9 and 1 to 19 times in any series of tests of sufficient duration.

A variation of 2.5 entries per apple by this method of analysis with 60 larvae used to determine each mean would occur between 1 in 20 repetitions and 1 in 50 repetitions due

to chance alone. As 1 in 20 is usually accepted as significant odds a variation of 2.5 entries magnitude would undoubtedly be significant.

In two series of tests where 60 larvae were used to determine each mean an average difference of 3.0 entries per apple occurred. The probability is less than 1 in 100 that this wide a variation would occur within a single population that was being uniformly influenced by its environment.

In two series of tests in which over 100 larvae were used to determine each mean an average difference of 1.4 entries per apple occurred. The probability is between 2 in 10 and 1 in 10 that this variation is due to chance. In two other series of tests of the same size a difference between the means of 2.1 entries per apple occurred. The probability is less than 1 in 100 that this wide a variation would occur due to chance alone.

In Table XXIII by the method of the difference of means of small samples a variation of 1.5 entries per apple in two groups of 5 and 4 series respectively selected at random gave a probability of 1 in 10 that the variation was due to chance. In two other groups of 5 and 3 series of mixtures respectively a difference of 2.0 entries per apple gave a probability of between 1 in 20 and 1 in 50 that this large a

variation was due to chance. As odds of 1 in 20 are generally considered significant a variation of 2.0 entries per apple could be considered significant when groups as small as 4 or 5 series of mixtures were compared.

Two groups from Table XXIII with 9 series in one and 10 series in the other had a variation of 0.8 entries per apple. The probability was slightly more than 1 in 10 that this variation was due to chance. Two other groups of 10 series each had a variation of 1.4 entries per apple. The probability in this instance was between 1 in 50 and 1 in 100 that the variation was due to chance. These figures indicate that a variation of slightly less than 1.4 entries per apple is significant.

RESULTS

In Table VII are listed the various mixtures that were tested, arranged in the order of decreasing larvicidal value. Chemical formulae, molecular weight, physical state, melting point and solubility in oil are included as a brief description of each chemical compound used.

Table VII

UNEMULSIFIED IMPREGNATED WHITE OIL AS A LARVICIDE
FOR CODLING MOTH

Item No.	Material Added to White Oil	Formulae	Molecular Wt. (1)	Phys. St. at Room Temp (2)	M.P. Deg. C. (1)	Sol. in Oil (3)	Amt. Added	No. Lar. Used (4)	Percentage of Control of Entries
1	W.O.(5) sat. with tannic acid (6)	$C_{14}H_{10}O_9$	322	S	126	+	50%	30	100
	W.O. cont. 1% nicotine (7)	$C_{10}H_{14}N_2$	162	L	B.P. 247	-	50%		
2	W.O.sat. with tannic acid	$C_{14}H_{10}O_9$	322	S	126	+	50%	30	100
	W.O.sat. with nicotine	$C_{10}H_{14}N_2$	162	L	B.P. 247	+	50%		
3	Nicotine sulphate(8)	$C_{10}H_{14}N_2H_2SO_4$	260	L		-	2%	180	100
4	Nicotine sulphate	$C_{10}H_{14}N_2H_2SO_4$	260	L		-	1%	210	96
5	W.O.cont. 1% nicotine	$C_{10}H_{14}N_2$	162	L	B.P. 247	-	50%	20	89
	W.O.Sat. with Goulac (9)			S		+	50%		
6	Nicotine	$C_{10}H_{14}N_2$	162	L	B.P. 247	-	0.5%	30	83
7	W.O.sat. with nicotine	$C_{10}H_{14}N_2$	162	L	B.P. 247	+	50%	30	78
8	1-3-8 Tri-nitro-naphthalene	$C_{10}H_5(NO_2)_3$	263	S	122	-	1%	30	71
9	Methyl Salicylate	$HO\ C_6H_4COO\ CH_3$	152	L	-8	+	2%	30	71
10	Para-di-bromo-benzene	$C_6H_4Br_2$	236	S	89	-	20%	30	61
11	Naphthalene	$C_{10}H_8$	128	S	80	+	10%	30	61
12	Copper cyanide	$Cu_2(CN)_2$	179	S		-	2%	60	59
13	Copper oleate	$Cu(C_{17}H_{33}COO)_2$	626	S		+	2%	150	59
	Ground Pyrethrum	$(C\ H\ O)$							

12	Copper cyanide		179	S		-	2%	60	52
13	Copper oleate	$Cu(C_{17}H_{33}COO)_2$	626	S		+	2%	150	59
14	Ground Pyrethrum	$(C_{21}H_{30}O)_3$	330	S		+	12%	30	55
15	Alpha Naphthylamine	$C_{10}H_7NH_2$	143	S	50	+	2%	30	55
16	Iodine	I_2	254	S	112	-	2%	30	55
17	Beta-iodo-naphthalene	$C_{10}H_7I$	254	S	54	+	2%	30	55
18	Nicotine sulphate	$C_{10}H_{14}N_2H_2SO_4$	260	L		-	.4%	150	52
19	Meta-di-nitro-benzene	$C_6H_4(NO_2)_2$	168	S	90	-	2%	90	50
20	Di-bromo-ortho-cresol	$Br_2CH_3C_6H_2OH$	266	S	55	+	1%	30	48
21	Para-chloro-aniline	$Cl\ C_6H_4NH_2$	128	S	70	-	2%	30	48
22	Para-nitro-iodo-benzene	$I\ C_6H_4NO_2$	203	S	172	-	2%	30	48
23	3-5 Di-bromo-ortho-cresol	$Br_2CH_3C_6H_2OH$	266	S	55	+	5%	70	48
24	Xylene	$C_6H_4(CH_3)_2$	106	L	B.P. 135	+	2%	60	48
25	Allyl-iso-thio-cyanate	$CH_2CH\ CH_2NCS$	99	L	B.P. 143	+	1%	60	48
26	Beta-chloro-naphthalene	$C_{10}H_7Cl$	163	S	56	+	2%	60	48
27	3-5 Di-bromo-ortho cresol	$Br_2CH_3C_6H_2OH$	266	S	55	+	2%	120	43
28	Carbon-tetra-chloride	$C\ Cl_4$	154	L	-24	+	1%	20	43
29	Cetyl Arsenite	$(C_{16}H_{33})_2HAsO_3$	574	S		+	1%	20	43
30	Piperine	$C_5H_{10}N\ CO\ C_4H_4$ $C_6H_3O_2CH_2$	285	S	129	-	2%	60	43
31	Toluene	$C_6H_5CH_3$	92	L	B.P. 109	+	2%	60	43
32	Ortho-Toluidine	$CH_3C_6H_4NH_2$	107	L	B.P. 198	+	2%	50	41
33	Thymol	$CH_3C_6H_3(OH)$ C_3H_7	150	S	50	+	2%	50	41
34	Ortho-di-chloro-benzene	$C_6H_4Cl_2$	147	L	B.P. 179	+	2%	70	41
35	Iodine	I_2	254	S	112	+	1%	50	41

34	benzene		147	L	+12	+	2%	10	39
35	Iodine	I_2	254	S	112	+	1%	50	41
36	Fluorbenzene	C_6H_5F	96	L		+	2%	30	39
37	Beta-iodo-naphthalene	$C_{10}H_7I$	254	S	54	+	20%	30	39
38	Barium stearate	$Ba(CH_3(CH_2)_{16}COO)_2$	702	S		-	1%	30	39
39	Aniline	$C_6H_5NH_2$	93	L	-6	+	2%	60	39
40	Para-di-iodo-benzene	$C_6H_4I_2$	330	S	129	-	10%	30	39
41	Tetra-chloro-ethylene	$CCl_2C\ Cl_2$	166	L	-19	+	20%	30	39
42	2-4 Dichlor-6-phenyl-phenol	$Cl_2C_6H_5C_6H_2OH$	239	S		-	2%	30	39
43	Alpha-nitro-naphthalene	$C_{10}H_7NO_2$	173	S	61	+	2%	60	36
44	Copper oleate (Excess acid)	$Cu(C_{17}H_{33}COO)_2$	626	S		-	5%	60	36
45	Para-nitro-chloro-benzene	$C_6H_4ClNO_2$	157	S	83	+	2%	60	36
46	2-5 Di-chloro-aniline	$NH_2C_6H_3Cl_2$	162	S	50	+	2%	60	36
47	1-2-4-5 Tetra-chloro-benzene	$C_6H_2Cl_4$	216	S	140	+	1%	60	36
48	Mono-chloro-naphthalene	$C_{10}H_7Cl$	163	L		+	2%	60	32
49	Copper sulfo-cyanide	CuCNS	122	S	1084	-	2%	60	32
50	Rotenone	$C_{23}H_{22}O_6$	394	S		-	1%	30	32
51	Stearic Acid Arsenious oxide	$C_{17}H_{35}COOH$ As_2O_3	284 198	S S	69 Sub. 218	- -	2% 1%	60	32
52	Ortho-nitro-chloro-benzene	$C_6H_4ClNO_2$	157	S	32	+	2%	60	32
53	Barium oleate	$Ba(C_{17}H_{33}COO)_2$	700	S		-	1%	50	27
54	Para-di-bromo-benzene	$C_6H_4Br_2$	236	S	89	+	1%	60	27
55	Benzene	C_6H_6	78	L	5	+	2%	60	27
56	W.O.(50-55 Vis.) Chloroform Rotenone	 $CHCl_3$ $C_{23}H_{22}O_6$	 119 394	 L S	 -57	 + +	 10% .074%	60	27
	1-nitro-2-	$NO_2C_{10}H_6OH$							

55	Benzene		78	L	2	+	2%	60	21
56	W.O.(50-55 Vis.) Chloroform Rotenone	$CHCl_3$ $C_{23}H_{22}O_6$	119 394	L S	-57	+ +	10% .074%	60	27
57	1-nitro-2-naphthol	$NO_2C_{10}H_6OH$	189	S	103	-	2%	90	25
58	Lamp black Sodium arsenite	Na_2HAsO_3	170	S		-	2% 1%	30	25
59	Benzyl arsenic acid	$C_6H_5CH_2AsO_3H_2$	210	S		-	2%	30	25
60	Ortho-dichloro-benzene	$C_6H_4Cl_2$	147	L	B.P. 179	+	2%	60	25
61	Thallous Malonate	$Tl_2C_3H_2O_4$	511	S		-	2%	60	25
62	Chloroform-Rotenone	$CH\ Cl_3$ $C_{23}H_{22}O_6$	119 394	L S	-57	+ +	10% .074%	50	23
63	Sodium cyanide	Na CN	49	S		-	1%	50	23
64	Naphthalene	$C_{10}H_8$	128	S	80	+	2%	90	23
65	Meta-di-chloro benzene	$C_6H_4Cl_2$	147	L	-18	+	1%	60	20
66	Phenol	C_6H_5OH	94	L		-	2%	60	20
67	Tri-nitro-resorcinol	$(NO_2)_3C_6H(OH)_2$	245	S	174	-	1%	60	20
68	Copper oleate	$Cu(C_{17}H_{33}COO)_2$	626	S		-	5%	110	20
69	1-2-4-5 Tetra-chloro-benzene	$C_6H_2Cl_4$	216	S	140	-	1%	60	20
70	Ortho-phenyl-phenol	$C_6H_5C_6H_4OH$	170	S		+-	2%	120	20
71	9-10 Di-chloro-anthracene	$C_{14}H_8Cl_2$	247	S	209	-	1%	50	18
72	Tri-hexa-chloro-naphthalene			S		+	1%	50	18
73	Menthol	$C_{10}H_{19}OH$	156	S	43	+	2%	50	18
74	Para-di-chloro-benzene	$C_6H_4Cl_2$	147	S	53	+	20%	30	16
75	Hydro-fluoride	$HF\ H_2O$	38	L	B.P. 120	-	2%	60	16
76	Para-di-chloro-benzene	$C_6H_4Cl_2$	147	S	53	+	10%	30	16
77	Sodium sulfocyanate	NaCNS	81	S	287	-	1%	60	16

75	Hydro-fluoride		38	L	120	-	2%	60	16
76	Para-di-chloro-benzene	$C_6H_4Cl_2$	147	S	53	+	10%	30	16
77	Sodium sulfocyanate	NaCNS	81	S	287	-	1%	60	16
78	Di-nitro-phenol	$(NO_2)_2\ C_6H_3(OH)$	184	S	144	-	1%	60	16
79	Sodium ortho-phenyl-phenylate	$NaO\ C_6H_4C_6H_5$	192	L		-	2%	60	16
80	Phenyl-iso-thio-cyanate	C_6H_5NCS	135	L	B.P. -21	+	1%	60	14
81	Tri-phenyl-arsine	$(C_6H_5)_3As$	306	S	59	+	1%	110	11
82	Beta-bromo-naphthalene	$C_{10}H_7Br$	207	S	55	+	2%	60	9
83	Di-chloro-nitro-benzene	$Cl_2C_6H_3NO_2$	192	S	53	+	1%	50	9
84	Para-para-dichloro-di-phenol	$C_6H_4Cl\ C_6H_4Cl$	234	S	148	-	1%	60	9
85	Ortho-Cresol	$CH_3C_6H_4OH$	108	L	30	-	2%	60	9
86	Beta-naphthol	$C_{10}H_7OH$	144	S	122	-	1%	70	9
87	Para-di-chloro-benzene	$C_6H_4Cl_2$	147	S	53	+	1%	60	9
88	2-Chloro-6-phenyl phenol	$C_6H_5Cl\ C_6H_3OH$	207	L		+	2%	90	7
89	3-5 Di-nitro-ortho-cresol	$C_6H_2(NO_2)_2\ (CH_3)\ OH$	198	S	85	-	1%	60	5
90	Beta-iodo-naphthalene	$C_{10}H_7I$	254	S	54	+	1%	40	5
91	Chloropicrin	$C\ Cl_3NO_2$	164	L	-69	+	1%	60	5
92	Bromopicrin	$C\ Br_3NO_2$	298	L	10	+	1%	50	5
93	Bromine	Br_2	160	L	-7	+	1%	50	5
94	Chlorine	Cl_2	71	G	-101	+	2%	50	5
95	Nitro-benzene	$C_6H_5NO_2$	123	L	5	+	2%	30	2
96	Pyridine	C_5H_5N	79	L	B.P. 115	+	2%	60	2
97	Sodium chloro-ortho-cyclohexyl phenate	$NaO\ C_6H_3Cl\ C_6H_{11}$	233	S		+	2%	90	2
	Di-methyl-amino-	$(CH_3)_2NH\ C_6H_5$							

96	Pyridine	C_5H_5N	79	L	115	+	2%	60	2
97	Sodium chloro-ortho-cyclohexyl phenate	$NaO\ C_6H_3Cl\ C_6H_{11}$	233	S		+	2%	90	2
98	p-Dimethyl amino-benzyl-aldehyde	$(CH_3)_2NH_2C_6H_2\ CHO$	112	S	73	-	2%	30	2
99	Cyanamide	$CH\ NH_2$	42	S	46	-	2%	30	2
100	Tetra-chloro-ethylene	$C\ Cl_2C\ Cl_2$	166	L	-19	+	1%	60	2
101	Bromo-form	$CH\ Br_3$	253	L	9	+	1%	60	2
102	Beta-chloro-naphthalene	$C_{10}H_7Cl$	163	S	56	+	20%	30	2
103	122-4 Tri-chloro-benzene	$C_6H_3Cl_3$	181	L	16	+	1%	60	2
104	Di-nitro-naphthalene	$C_{10}H_6(NC_2)_2$	218	S	214	-	1%	60	2
105	Phenyl-alpha-naphthylamine	$C_{10}H_7NH\ C_6H_5$	219	S	60	+	1%	60	2
106	Ortho-cyclo-hexyl-phenol	$C_6H_{11}C_6H_4OH$	174	S	57	+	2%	30	2
107	Beta-bromo-naphthalene	$C_{10}H_7Br$	207	S	59	+	20%	30	2
108	Chloroform	$C\ H\ Cl_3$	119	L	-57	+	10%	60	2
109	1 pt. lamp black 5 pts. arsenious oxide	As_2O_3	198	S	Subl. 218	+	3%	30	2
110	Ortho-phenyl phenol	$C_6H_5C_6H_4OH$	170	S		-	10%	30	2
111	White Oil-Control			L				1300	0
112	Phenacyl chloride	$C_6H_5CO\ C\ H_2Cl$	155	S	56	-	2%	40	-2
113	Di-bromo-naphthalene	$C_{10}H_6Br_2$	286	S	66	-	1%	60	-7
114	Di-phenyl-amino-arsine	$(C_6H_5)_2NH_2As$	245	S		-	2%	30	-7
115	Tetra-chloro-benzene	$C_6H_2Cl_4$	216	L	45	-	5%	60	-7
116	Straw-oil (10)			L			100%	30	-7
117	Red Pepper	Oil Extract		S		+	25%	30	-7
		$C_6H_4(CH)_2C_6H_4$							

115	benzene		216	L	42	-	2%	60	-7
116	Straw-oil (10)			L			100%	30	-7
117	Red Pepper	Oil Extract		S		+	25%	30	-7
118	Anthracene	$C_6H_4(CH)_2C_6H_4$	178	S	216	-	1%	60	-7
119	Cumidine	$NH_2C_6H_4CH(CH_3)_2$	135	L	20	+	2%	40	-9
120	Chlora-acetone	$CH_2Cl\ CO\ CH_3$	92	L	B.P. 119	+	1%	60	-9
121	1-3-5 Tri-nitro-benzene	$C_6H_3(NO_2)_3$	213	S	112	-	1%	60	-9
122	2-4 Di-chloro-phenol	$Cl_2C_6H_3OH$	165	S	40	+	1%	60	-9
123	Para-nitro-aniline	$NO_2C_6H_4NH_2$	138	S	146	-	1%	50	-14
124	Beta-chloro-ethyl-para-toluene sulfonate	$CH_3C_6H_4SO_4(CH_2)_2Cl$	250	S	19	-	1%	60	-14
125	Bromo-beta-naphthol	$Br\ C_{10}H_7OH$	223	S	60	-	1%	60	-14
126	Cetyl fluoride	$C_{16}H_{33}F$	244	S		+	2%	30	-14
127	Carbon disulfide	CS_2	76	L	-113	+	2%	30	-14
128	Iodoform	CHI_3	394	S	Subl. 119	-	1%	40	-14
129	Lamp black Sodium fluoride	NaF	42	S	992	-	2% 1%	20	-14
130	Para-di-iodo-benzene	$C_6H_4I_2$	330	S	129	+	1%	40	-14
131	2-4 Di-nitro-chloro-benzene	$Cl\ C_6H_3(NO_2)_2$	202	S	47	-	1%	60	-18
132	W.O.sat. with tannic acid	$C_{14}H_{10}O_9$	322	S	200	+	Sat.	30	-18
133	Arsenious oxide	As_2O_3	198	S	Subl. 218	-	1%	60	-18
134	Cyanogen bromide	$CN\ Br$	106	S	52	-	1%	60	-20
135	2-4 Di-nitro-bromo-benzene	$Br\ C_6H_3(NO_2)_2$	247	S	70	-	2%	50	-23
136	Cetyl alcohol	$C_{16}H_{33}OH$	242	S	50	+	2%	60	-25
137	Metallic arsenic	As_4	300	S	Subl. 446	+	1%	60	-25

131	2-4 Di-nitro-chloro-benzene	Cl $C_6H_3(NO_2)_2$	202	S	47	-	1%	60	-18
132	W.O.sat. with tannic acid	$C_{14}H_{10}O_9$	322	S	200	+	Sat.	30	-18
133	Arsenious oxide	As_2O_3	198	S	Subl. 218	-	1%	60	-18
134	Cyanogen bromide	CN Br	106	S	52	-	1%	60	-20
135	2-4 Di-nitro-bromo-benzene	Br $C_6H_3(NO_2)_2$	247	S	70	-	2%	50	-23
136	Cetyl alcohol	$C_{16}H_{33}OH$	242	S	50	+	2%	60	-25
137	Metallic arsenic	As_4	300	S	Subl. 446	+	1%	60	-25
138	p-Bromo-benzo-nitrile	Br C_6H_4CN	182	S	111	-	1%	60	-30
139	Beta-Naphthylamine	$C_{10}H_7NH_2$	143	S	111	-	2%	30	-30
140	Para-nitro-bromo-benzene	Br $C_6H_4NO_2$	203	S	121	-	2%	60	-32
141	Para-toluidene	$CH_3C_6H_4NH_2$	107	L	42	+	1%	30	-43

(1) Molecular weights and melting points are rounded to the nearest whole number. If the melting point covers more than one degree only the lowest figure is given.
(2) S= Solid; L= Liquid; G= Gas.
(3) + Indicates the amount added dissolved completely.
\- " " " " did not dissolve completely.
(4) 10 larvae used per apple.
(5) W.O.= White Oil- specifications given on page 51.
(6) A mixture, Item 1, of one part of White Oil saturated with tannic acid and one part of White Oil containing 1% nicotine was applied to the apples.
(7) Nicotine given is 50 per cent of Black Leaf 50.
(8) Nicotine sulfate given is 40 per cent of Black Leaf 40.
(9) Waste sulfite, Va. Agr. Exp. Sta. Bul. 277.
(10) Petroleum oil- Specific gravity 0.889, Viscosity 104, Absorption by H_2SO_4, 7%, Evaporation 0.19 per cent.

Nicotine and nicotine sulfate were the only materials giving more than 75 per cent control of entries. The control consisted of apples sprayed with White Oil, (Item 111, Table VII) so that approximately 35 per cent of the larvae were killed that would have made entries on unsprayed apples.

1-3-8 Tri-nitro-naphthalene, methyl salicylate, para-di-bromo-benzene, naphthalene, copper cyanide and copper oleate gave the highest percentage of control of the chemical compounds other than nicotine that were tried. They gave better control than pyrethrum extract, (Item 14, Table VII).

In 42 of the mixtures tested the material added was a liquid at room temperature. These mixtures gave an average of 35 per cent control. This rather high control was probably partly due to the better mixture obtainable between two liquids and partly due to the fact that nicotine falls in this group.

In 96 of the mixtures tested a solid was dispersed in the oil. The average control of these solid materials was 17 per cent. This relatively low average was probably partly due to the oil having coated some water soluble toxic constituents such as arsenious oxide, (Item 133, Table VII) and rendered them inactive under the conditions of the

investigation.

The only gas tested was chlorine, (Item 94, Table VII) which gave 5 per cent control.

In Table VIIa is given the percentage of control in relation to the molecular weight of the compound used.

In Table VIIb is given the percentage of the total number of mixtures tested in comparison with the percentage of control.

Table VIIa

Relation of Molecular Weight
To Toxicity To Codling Moth Larvae

Item No.	Percentage of Control	No. of Mixtures Used in Each Molecular Weight Range					
		Below 100	100-150	151-200	201-250	251-300	Above 300
1	100-76			1			
2	75-51		2	2	1	5	2
3	50-26	5	6	10	4	6	7
4	25-0	7	12	16	11	3	4
5	Below 0	3	5	5	10	2	3
6	Total No. in Each Weight Range	15	25	34	26	16	16

Table VIIb

Note: This table contains the same data as Table VIIa with Items 1-5 converted into percentages of Item 6 in that Table and Item 6 converted into percentages of the total number.

Item No.	Percentage of Control	Percentage of Total No. of Mixtures in Each Molecular Weight Range					
		Below 100	100-150	151-200	201-250	251-300	Above 300
1	100-76			3			
2	75-51		8	6	4	31	13
3	50-26	33	24	30	16	37	44
4	25-0	47	48	47	42	19	24
5	Below 0	20	20	14	38	13	19
6	Percentage of All Mixtures in Each Weight Range	11	19	27	20	12	12

These tables indicate that of the compounds used those that had molecular weights between 251 and 300 included the largest percentage of the mixtures tested that gave more than 50 per cent control, (Items 1 and 2, Table VIIb).

Compounds having molecular weights of above 300, (Item 2, Table VIIb) ranked next in percentage of the mixtures tried that gave more than 50 per cent control, but those that fell in the 151-200 group included the largest number of mixtures investigated.

None of the 15 mixtures tried that had molecular weights of less than 100 gave more than 48 per cent control.

While these relationships are based on too few compounds for any general conclusion, still the data indicate that the lighter molecules are not satisfactory for this type of insecticide. Compounds having molecular weights below 100 and possibly 150, seem to be of doubtful value.

A study of the solubility in oil of the materials tested as given in Table VII indicates that some of the most toxic materials, nicotine, 1-3-8 tri-nitro-naphthalene and copper cyanide are not soluble in oil.

Of all the materials tested as recorded in Table VII, nicotine, 1-3-8 tri-nitro-naphthalene, methyl salicylate, copper cyanide and copper oleate gave the highest percentage of control, when 2 per cent or less of the material was added.

Nicotine was the most effective and copper oleate the least. The others rank in the order named.

In Table VIII are listed all the aromatic and alipatic compounds studied which did not contain other elements or groups.

The aromatic compounds used gave an average of 20 per cent control of entries as compared with -2 per cent control of entries by the aliphatic compounds.

Methyl salicylate was the most toxic material tested in this group.

Table VIII

TOXICITY TO CODLING MOTH LARVAE OF UNEMULSIFIED WHITE OIL IMPREGNATED WITH ALIPHATIC AND AROMATIC CARBON COMPOUNDS

Item No.	Material Added to White Oil	Amount Added	No. Larvae Used	Average per Apple		Percentage of Control of Entries
				Stings	Entries	
1	Methyl salicylate	2%	30	0.0	1.3	71
2	Naphthalene	10%	30	0.0	1.7	61
3	Xylene	2%	60	0.0	2.3	48
4	Toluene	2%	60	0.17	2.5	43
5	Thymol	2%	50	0.2	2.6	41
6	Benzene	2%	60	0.5	3.2	27
7	Ortho-phenyl-phenol	2%	120	0.0	3.4	23
8	Naphthalene	2%	90	0.0	3.4	23
9	Phenol	2%	60	0.33	3.5	20
10	Menthol	2%	50	0.2	3.6	18
11	Ortho-Cresol	2%	60	0.33	4.0	9
12	Beta Naphthol	1%	70	0.14	4.0	9
13	Ortho-phenyl-phenol	10%	30	0.0	4.3	2
14	Ortho-cyclo-hexyl-phenol	2%	30	0.0	4.3	2
15	White Oil-Control	None	1300	0.19	4.4	0
16	Anthracene	1%	60	0.17	4.7	-7
17	White Oil saturated with tannic acid	Sat.	30	0.0	5.2	-18

9	Phenol	2%	60	0.33	3.5	20
10	Menthol	2%	50	0.2	3.6	18
11	Ortho-Cresol	2%	60	0.33	4.0	9
12	Beta Naphthol	1%	70	0.14	4.0	9
13	Crtho-phenyl-phenol	10%	30	0.0	4.3	2
14	Ortho-cyclo-hemyl-phenol	2%	30	0.0	4.3	2
15	White Oil-Control	None	1300	0.19	4.4	0
16	Anthracene	1%	60	0.17	4.7	-7
17	White Oil saturated with tannic acid	Sat.	30	0.0	5.2	-18
18	Cetyl Alcohol	2%	60	0.17	5.5	-25

SUMMARY

Item No.	No. of Mixtures Tested	Materials Tested	Percentage of Material Added	No. Larvae	Ave. Eat.per Apple	Average Percentage of Control
1	15	Aromatic carbon mixtures	1-10	840	3.5	20
2	2	Aliphatic carbon mixtures	2	110	4.5	-2

In Table IX are listed the compounds tested which contained the nitro group.

Many of these compounds are practically insoluble in oil. In fact, all the mixtures which gave negative control, (Items 17-21, Table IX) were apparently insoluble in oil as was the material which gave the best control, (Item 1, Table IX). The mixtures which contained the naphthalene group, (Items 1, 4, 7 and 15, Table IX) combined with the nitro group all gave a positive percentage of control. Iodine, (Item 3, Table IX) combined with nitro-benzene gave a higher percentage of control of entries than chloro- or bromo-nitro-benzene combinations.

1-3-8 Tri-nitro-naphthalene gave the highest percentage of control of any of the nitro mixtures tested.

Table IX

TOXICITY TO CODLING MOTH LARVAE OF UNEMULSIFIED WHITE OIL IMPREGNATED WITH COMPOUNDS CONTAINING THE NITRO GROUP

Item No.	Material Added to White Oil	Amount Added	No. Larvae Used	Average per Apple		Percentage of Control of Entries
				Stings	Entries	
1	1-3-8 Tri-nitro-naphthalene	1%	30	0.33	1.3	71
2	Meta-di-nitro-benzene	2%	90	0.0	2.2	50
3	Para-nitro-iodo-benzene	2%	30	0.33	2.3	48
4	Alpha-nitro-naphthalene	2%	60	0.33	2.8	36
5	Para-nitro-chloro-benzene	2%	60	0.0	2.8	36
6	Ortho-nitro-chloro-benzene	2%	60	0.0	3.0	32
7	1-Nitro-2-Naphthol	2%	90	0.33	3.3	25
8	Tri-nitro-resorcinol	1%	60	0.0	3.5	20
9	Di-nitro-phenol	1%	60	0.0	3.7	16
10	Di-chloro-nitro-benzene	1%	50	0.40	4.0	9
11	3-5 Di-nitro-ortho-cresol	1%	60	0.0	4.2	5
12	Bromo-picrin	1%	50	0.0	4.2	5
13	Chloro-picrin	1%	60	0.83	4.2	5
14	Nitro-benzene	2%	30	0.0	4.3	2
15	Di-nitro-naphthalene	1%	60	0.50	4.3	2
16	White Oil- Control		1300	0.19	4.4	0
17	1-3-5 Tri-nitro-benzene	1%	60	0.0	4.3	-9

8	Tri-nitro-resorcinol	1%	60	0.0	3.5	20
9	Di-nitro-phenol	1%	60	0.0	3.7	16
10	Di-chloro-nitro-benzene	1%	50	0.40	4.0	9
11	3-5 Di-nitro-ortho-cresol	1%	60	0.0	4.2	5
12	Bromo-picrin	1%	50	0.0	4.2	5
13	Chloro-picrin	1%	60	0.83	4.2	5
14	Nitro-benzene	2%	30	0.0	4.3	2
15	Di-nitro-naphthalene	1%	60	0.50	4.3	2
16	White Oil- Control		1300	0.19	4.4	0
17	1-3-5 Tri-nitro-benzene	1%	60	0.0	4.8	-9
18	Para-nitro-aniline	1%	50	0.0	5.0	-14
19	2-4 Di-nitro-chloro-benzene	1%	60	0.17	5.2	-18
20	2-4 Di-nitro-bromo-benzene	2%	50	0.40	5.4	-23
21	Para-nitro-bromo-benzene	2%	60	0.17	5.8	-32

SUMMARY

Item No.	No. of Mixtures Tested	Materials Tested	Percentage of Material Added	No. Larvae	Ave. Ent.per Apple	Average Percentage of Control
1	20	Nitro Mixtures	1-2	1130	3.8	14

In Table X are listed the mixtures tested which contained Iodine.

Iodine at 2 per cent (Item 1, Table X) was the most toxic mixture used in this series.

Iodoform, (Item 10, Table X) gave -14 per cent control of entries.

Beta-iodo-naphthalene at 2 per cent (Item 2, Table X) was more toxic than at 1 per cent or 20 per cent, (Items 6 and 7, Table X).

Table X

TOXICITY TO CODLING MOTH LARVAE OF UNEMULSIFIED WHITE OIL IMPREGNATED WITH IODINE OR IODO COMPOUNDS

Item No.	Material Added to White Oil	Amount Added	No. Larvae Used	Average per Apple		Percentage of Control of Entries
				Stings	Entries	
1	Iodine	2%	30	0.67	2.0	55
2	Beta-Iodo-Naphthalene	2%	30	0.0	2.0	55
3	Para-Nitro-Iodo-Benzene	2%	30	0.33	2.3	48
4	Iodine	1%	50	0.0	2.6	41
5	Para-di-iodo-benzene	10%	30	0.0	2.7	39
6	Beta-Iodo-Naphthalene	20%	30	0.0	2.7	39
7	Beta-Iodo-Naphthalene	1%	40	0.0	4.2	5
8	White Oil- Control	None	1300	0.19	4.4	0
9	Para-di-iodo-benzene	1%	40	0.25	5.0	-14
10	Iodoform	1%	40	0.25	5.0	-14

SUMMARY

Item No.	No. of Mixtures Tested	Materials Tested	Percentage of Material Added	No. Larvae	Ave. Ent. per Apple	Average Percentage of Control
1	9	Iodine Mixtures	1-2	320	3.2	27

In Table XI are listed the mixtures that were tested which contained bromine.

Para-di-bromo-benzene, (Item 1, Table XI) was the most toxic material tested in this series.

3-5 Di-bromo-ortho-cresol at 1, 2 and 5 per cent, (Items 2, 3 and 4, Table XI) also showed considerable toxicity.

Six bromine compounds, (Items 12-17, Table XI) all were apparently insoluble in oil and gave negative control.

Table XI

TOXICITY TO CODLING MOTH LARVAE OF UNEMULSIFIED WHITE OIL IMPREGNATED WITH BROMINE OR BROMO-COMPOUNDS

Item No.	Material Added to White Oil	Amount Added	No. Larvae Used	Average per Apple		Percentage of Control of Entries
				Stings	Entries	
1	Para-di-bromo-benzene	20%	30	0.0	1.7	61
2	3-5 Di-bromo-ortho-cresol	1%	30	0.67	2.3	48
3	3-5 Di-bromo-ortho-cresol	5%	70	0.0	2.3	48
4	3-5 Di-bromo-ortho-cresol	2%	120	0.17	2.5	43
5	Para-di-bromo-benzene	1%	60	0.17	3.2	27
6	Beta-bromo-naphthalene	2%	60	0.33	4.0	9
7	Bromine	1%	50	0.20	4.2	5
8	Bromo-picrin	1%	50	0.0	4.2	5
9	Beta-bromo-naphthalene	20%	30	0.0	4.3	2
10	Bromo-form	1%	60	0.33	4.3	2
11	White Oil- Control	None	1300	0.19	4.4	0
12	Di-bromo-naphthalene	1%	60	0.17	4.5	-2
13	Bromo-beta-naphthol	1%	60	0.17	5.0	-14
14	Cyanogen bromide	1%	60	0.0	5.3	-20
15	2-4 Di-nitro-bromo-benzene	2%	50	0.40	5.4	-23
16	Bromo-benzo-nitrile	1%	60	0.33	5.7	-30
17	Para-nitro-bromo-benzene	2%	60	0.17	5.8	-32

SUMMARY

8	Bromo-picrin	1%	50	0.0	4.2	5
9	Beta-bromo-naphthalene	20%	30	0.0	4.3	2
10	Bromo-form	1%	60	0.33	4.3	2
11	White Oil- Control	None	1300	0.19	4.4	0
12	Di-bromo-naphthalene	1%	60	0.17	4.5	-2
13	Bromo-beta-naphthol	1%	60	0.17	5.0	-14
14	Cyanogen bromide	1%	60	0.0	5.3	-20
15	2-4 Di-nitro-bromo-benzene	2%	50	0.40	5.4	-23
16	Bromo-benzo-nitrile	1%	60	0.33	5.7	-30
17	Para-nitro-bromo-benzene	2%	60	0.17	5.8	-32

SUMMARY

Item No.	No. of Mixtures Tested	Materials Tested	Percentage of Material Added	No. Larvae	Ave. Ent. per Apple	Average Percentage of Control
1	16	Bromine Mixtures	1-20	910	4.0	9

In Table XII are listed all the mixtures that were tested that contained chlorine.

Beta-chloro-naphthalene, (Item 1, Table XII) and para-chloro-aniline, (Item 2, Table XII) gave the higheet percentage of control.

Ortho-di-chloro-benzene, (Items 4 and 12, Table XII) gave a higher percentage of control than meta-di-chloro-benzene, (Item 14, Table XII) or para-di-chloro-benzene, (Items 17, 18 and 21, Table XII).

Tetra-chloro-benzene at 1 per cent, (Items 7 and 13, Table XII) gave a higher percentage of control than 5 per cent tetra-chloro-benzene, (Item 31, Table XII).

Chlorine, chloropicrin, phenacyl chloride and chloro-acetone, (Items 23, 24, 30 and 32, Table XII) which in the gaseous state are extremely irritating were found to be practically non-toxic to codling moth larvae 24 hours after they were applied to the apples.

Table XII

TOXICITY TO CODLING MOTH LARVAE OF UNEMULSIFIED WHITE OIL IMPREGNATED WITH CHLORINE OR CHLORINE COMPOUNDS

Item No.	Material Added to White Oil	Amount Added	No. Larvae Used	Average per Apple Stings	Average per Apple Entries	Percentage of Control of Entries
1	Beta-chloro-naphthalene	2%	60	0.33	2.3	48
2	Para-chloro-aniline	2%	30	0.0	2.3	48
3	Carbon-tetra-chloride	1%	20	1.0	2.5	43
4	Ortho-di-chloro-benzene	2%	70	0.14	2.6	41
5	2-4 Di-chloro-6-phenyl-phenol	2%	30	0.0	2.7	39
6	Tetra-chloro-ethylene	20%	30	0.0	2.7	39
7	1-2-4-5 Tetra-chloro-benzene	1%	60	0.17	2.8	36
8	Para-nitro-chloro-benzene	2%	60	0.0	2.8	36
9	2-5 Di-chloro-aniline	2%	60	0.17	2.8	36
10	Ortho-nitro-chloro-benzene	2%	60	0.0	3.0	32
11	Mono-chloro-naphthalene	2%	60	0.17	3.0	32
12	Ortho-di-chloro-benzene	2%	60	0.0	3.3	25
13	1-2-4-5 Tetra-chloro-benzene	1%	60	0.0	3.5	20
14	Meta-di-chloro-benzene	1%	60	0.67	3.5	20
15	Tri-hexa-chloro-naphthalene	1%	50	0.0	3.6	18
16	9-10 Di-chloro-anthracene	1%	50	0.0	3.6	18
17	Para-di-chloro-benzene	10%	30	0.0	3.7	16

18	Para-di-chloro-benzene	20%	30	0.0	3.7	16
19	Di-chloro-nitro-benzene	1%	50	0.40	4.0	9
20	Para-para-dichloro-di-phenol	1%	60	0.50	4.0	9
21	Para-di-chloro-benzene	1%	60	0.0	4.0	9
22	2-Chloro-6-phenyl-phenol	2%	90	0.56	4.1	7
23	Chlorine	2%	50	0.20	4.2	5
24	Chloro-picrin	1%	60	0.83	4.2	5
25	Sodium chloro-ortho-cyclohexyl-phenate	2%	90	0.11	4.3	2
26	Tetra-chloro-ethylene	1%	60	0.17	4.3	2
27	1-2-4 Tri-chloro-benzene	1%	60	0.0	4.3	2
28	Beta-chloro-naphthalene	20%	30	0.0	4.3	2
29	White Oil- Control	None	1300	0.19	4.4	0
30	Phenacyl chloride	2%	40	0.5	4.5	-2
31	Tetra-chloro-benzene	5%	60	0.17	4.7	-7
32	Chloro-acetone	1%	60	0.0	4.8	-9
33	2-4 Di-chloro-phenol	1%	60	0.17	4.8	-9
34	Beta-chloro-ethyl para-toluene-sulfonate	1%	60	0.48	5.0	-14
35	2-4 Di-nitro-chloro-benzene	1%	60	0.17	5.2	-18

SUMMARY

Item No.	No. of Mixtures Tested	Materials Tested	Percentage of Material Added	No. Larvae	Ave. Ent. per Apple	Average Percentage of Control
1	34	Chlorine Mixtures	1-20	1830	3.7	16

In Table XIII are listed the compounds that were tested which contained the amino group.

Alpha naphthylamine, (Item 1, Table XIII) was the most toxic material tested in this series.

Ortho-toluidine, (Item 3, Table XIII) gave 41 per cent control as compared with -43 per cent control obtained with para-toluidine.

Seven of the twelve amino mixtures tested gave practically no control or negative control.

Table XIII

TOXICITY TO CODLING MOTH LARVAE OF UNEMULSIFIED WHITE OIL IMPREGNATED WITH COMPOUNDS CONTAINING THE AMINO GROUP

Item No.	Material Added to White Oil	Amount Added	No. Larvae Used	Average per Apple Stings	Average per Apple Entries	Percentage of Control of Entries
1	Alpha naphthylamine	2%	30	0.0	2.0	55
2	Para-chloro-aniline	2%	30	0.0	2.3	48
3	Ortho-toluidine	2%	50	0.40	2.6	41
4	Aniline	2%	60	0.17	2.7	39
5	2-5 Di-chloro-aniline	2%	60	0.17	2.8	36
6	p-Dimethyl amino-benzyl-aldehyde	2%	30	0.67	4.3	2
7	Phenyl-alpha-naphthylamine	1%	60	0.17	4.3	2
8	Cyanamide	2%	30	0.0	4.3	2
9	White Oil- Control	None	1300	0.19	4.4	0
10	Di-phenyl-amino-arsine	2%	30	0.0	4.7	-7
11	Cumidine	2%	40	0.0	4.8	-9
12	Beta Naphthylamine	2%	30	0.0	5.7	-30
13	Para-Toluidene	1%	30	0.0	6.3	-43

SUMMARY

Item No.	No. of Mixtures Tested	Materials Tested	Percentage of Material Added	No. Larvae	Ave. Ent. per Apple	Average Percentage of Control
1	12	Amino Mixtures	1-2	480	3.9	11

In Table XIV are listed the results obtained with seven elements in various mixtures.

The copper mixtures gave the best results of the materials tested.

Organic arsenite, fluorine and barium were moderately toxic.

Cetyl arsenite, (Item 3, Table XIV) was more toxic than any of the arsines tested.

Inorganic arsenic and fluorine had very little toxicity when mixed with oil.

Carbon disulfide gave a negative percentage of control.

Table XIV

TOXICITY TO CODLING MOTH LARVAE OF UNEMULSIFIED WHITE OIL IMPREGNATED WITH COPPER, BARIUM, THALLIUM, SODIUM, ARSENIC, FLUORINE AND SULPHUR COMPOUNDS AND METALLIC ARSENIC

Item No.	Material Added to White Oil	Amount Added	No. Larvae Used	Average per Apple		Percentage of Control of Entries
				Stings	Entries	
1	Copper oleate	2%	150	0.27	1.8	59
2	Copper cyanide	2%	60	0.0	1.8	59
3	Cetyl arsenite	1%	20	0.0	2.5	43
4	Fluorobenzene	2%	30	0.0	2.7	39
5	Barium stearate	1%	30	0.0	2.7	39
6	Copper oleate (Excess acid)	5%	60	0.8	2.8	36
7	Stearic acid Arsenious oxide	2% 1%	60	0.5	3.0	32
8	Copper sulfocyanide	2%	50	0.0	3.0	32
9	Barium oleate	1%	50	0.0	3.2	27
10	Lamp black Sodium arsenite	2% 1%	30	0.0	3.3	25
11	Benzyl arsenic acid	2%	30	0.0	3.3	25
12	Thallous malonate	2%	60	0.33	3.3	25
13	Sodium cyanide	1%	50	0.20	3.4	23
14	Copper oleate	5%	110	0.18	3.5	20
15	Sodium sulfocyanate	1%	60	0.0	3.7	16
16	Sodium-ortho-phenyl-phenylate	2%	60	0.67	3.7	16
17	Hydro-fluoride	2%	60	0.5	3.7	16

10	Sodium arsenite	1%	30	0.0	3.3	25
11	Benzyl arsenic acid	2%	30	0.0	3.3	25
12	Thallous malonate	2%	60	0.33	3.3	25
13	Sodium cyanide	1%	50	0.20	3.4	23
14	Copper oleate	5%	110	0.18	3.5	20
15	Sodium sulfocyanate	1%	60	0.0	3.7	16
16	Sodium-ortho-phenyl-phenylate	2%	60	0.67	3.7	16
17	Hydro-fluoride	2%	60	0.5	3.7	16
18	Tri-phenyl-arsine	1%	110	0.0	3.9	11
19	1 part lamp black 5 parts arsenious oxide	3%	30	0.33	4.3	2
20	White Oil- Control	None	1300	0.19	4.4	0
21	Cetyl fluoride	2%	30	0 .0	5.0	- 14
22	Lamp black Sodium fluoride	2% 1%	30	0.25	5.0	- 14
23	Carbon disulfide	2%	30	0.0	5.0	-14
24	Arsenious oxide	1%	60	0.17	5.2	- 18
25	Metallic arsenic	1%	60	0.0	5.5	- 25

SUMMARY

Item No.	No. of Mixtures Tested	Materials Tested	Percentage of Material Added	No. Larvae	Ave. Ent.per Apple	Average Percentage of Control
1	5	Copper mixtures	2-5	440	2.6	41
2	2	Barium mixtures	1	80	2.9	34
3	8	Arsenic mixtures	1-2.5	400	3.9	11
4	4	Fluorine mixtures	2	140	4.1	7

In Table XV are listed the plant extract and related compounds that were tested.

Nicotine, pyrethrum and rotenone were toxic in the order listed. Nicotine was much superior to the others.

Red pepper extract was non-toxic, (Item 17, Table XV).

Piperine, (Item 10, Table XV) showed moderate toxicity.

Pyridine, (Item 15, Table XV) showed no toxicity.

Table XV

TOXICITY TO CODLING MOTH LARVAE OF UNEMULSIFIED WHITE OIL IMPREGNATED WITH PLANT EXTRACTS, PIPERINE AND PYRIDINE MIXTURES

Item No.	Material Added to White Oil	Amount Added	No. Larvae Used	Average per Apple		Percentage of Control of Entries
				Stings	Entries	
1	White Oil saturated with tannic acid White oil containing 1% nicotine	50% 50%	30	0.0	0.0	100
2	White oil saturated with tannic acid White Oil saturated with nicotine	50% 50%	30	0.0	0.0	100
3	Nicotine sulfate	2%	180	0.0	0.0	100
4	Nicotine sulfate	1%	210	0.0	0.2	96
5	White oil containing 1% nicotine White oil saturated with goulac	50% 50%	20	0.0	0.5	89
6	White oil containing 1% nicotine	50%	30	0.0	0.7	83
7	White oil saturated with nicotine	50%	30	0.0	1.0	78
8	Ground Pyrethrum	12%	30	0.0	2.0	55
9	Nicotine sulfate	0.4%	150	0.0	2.1	52
10	Piperine	2%	60	0.5	2.5	43
11	Rotenone	1%	30	0.0	3.0	32
12	W.O.(50-55 Vis.) Chloroform Rotenone	10% 0.074%	60	0.17	3.2	27
13	Chloroform Rotenone	10% 0.074%	50	0.6	3.4	23

5	1% nicotine White oil saturated with goulac	50% 50%	20	0.0	0.5	89
6	White oil containing 1% nicotine	50%	30	0.0	0.7	83
7	White oil saturated with nicotine	50%	30	0.0	1.0	78
8	Ground Pyrethrum	12%	30	0.0	2.0	55
9	Nicotine sulfate	0.4%	150	0.0	2.1	52
10	Piperine	2%	60	0.5	2.5	43
11	Rotenone	1%	30	0.0	3.0	32
12	W.O.(50-55 Vis.) Chloroform Rotenone	10% 0.074%	60	0.17	3.2	27
13	Chloroform Rotenone	10% 0.074%	50	0.6	3.4	23
14	Chloroform	10%	60	0.33	4.3	2
15	Pyridine	2%	60	0.17	4.3	2
16	White Oil- Control	None	1300	0.19	4.4	0
17	Red Pepper	25%	30	0.0	4.7	-7

SUMMARY

Item No.	No. of Mixtures Tested	Materials Tested	Percentage of Material Added	No. Larvae	Ave. Ent. per Apple	Average Percentage of Control
1	16	Plant Extracts, Piperine and Pyridine Mixtures	1-25	1060	2.0	55

In Table XVI are listed all the mixtures that were used which contained the benzene ring.

Methyl salicylate, (Item 1, Table XVI) gave the highest percentage of control of any of 66 mixtures tested that contained the benzene ring.

Hydroxyl or methyl or both radicals or iodine combined with the benzene ring, in general, improved the kill.

Bromine, Chlorine, amino or nitro groups combined with the benzene ring in general did not increase the toxicity in the mixtures tested.

Table XVI

TOXICITY TO CODLING MOTH LARVAE OF UNEMULSIFIED WHITE OIL IMPREGNATED WITH COMPOUNDS CONTAINING THE BENZENE RING

Item No.	Material Added to White Oil	Amount Added	No. Larvae Used	Average per Apple		Percentage of Control of Entries
				Stings	Entries	
1	Methyl salicylate	2%	30	0.0	1.3	71
2	Para-di-bromo-benzene	20%	30	0.0	1.7	61
3	Meta-di-nitro-benzene	2%	90	0.0	2.2	50
4	Para-chloro-aniline	2%	30	0.0	2.3	48
5	Xylene	2%	60	0.0	2.3	48
6	Para-nitro-iodo-benzene	2%	30	0.33	2.3	48
7	3-5 Di-bromo-ortho-benzene	1%	30	0.67	2.3	48
8	3-5 Di-bromo-ortho-cresol	5%	70	0.0	2.3	48
9	Piperine	2%	60	0.50	2.5	43
10	3-5 Di-bromo-ortho-cresol	2%	120	0.17	2.5	43
11	Toluene	2%	60	0.17	2.5	43
12	Ortho-di-chloro-benzene	2%	70	0.14	2.6	41
13	Ortho-toluidine	2%	50	0.40	2.6	41
14	Thymol	2%	50	0.2	2.6	41
15	2-4 Dichloro-6-phenyl phenol	2%	30	0.0	2.7	39
16	Aniline	2%	60	0.17	2.7	39
17	Fluoro-benzene	2%	30	0.0	2.7	39
18	Para-di-iodo-benzene	10%	30	0.0	2.7	39
19	1-2-4-5 Tetra-chloro-benzene	1%	60	0.17	2.8	36

17	Fluoro-benzene	2%	30	0.0	2.7	39
18	Para-di-iodo-benzene	10%	30	0.0	2.7	39
19	1-2-4-5 Tetra-chloro-benzene	1%	60	0.17	2.8	36
20	2-5 Di-chloro-aniline	2%	60	0.17	2.8	36
21	Para-nitro-chloro-benzene	2%	60	0.0	2.8	36
22	Ortho-nitro-chloro-benzene	2%	60	0.0	3.0	32
23	Para-di-bromo-benzene	1%	60	0.17	3.2	27
24	Benzene	2%	60	0.5	3.2	27
25	Benzyl arsenic acid	2%	30	0.0	3.2	27
26	Ortho-di-chloro-benzene	2%	60	0.0	3.3	25
27	1-2-4-5 Tetra-chloro-benzene	1%	60	0.0	3.5	20
28	Ortho-phenyl-phenol	2%	120	0.0	3.5	20
29	Meta-di-chloro-benzene	1%	60	0.67	3.5	20
30	Tri-nitro-resorcinol	1%	60	0.0	3.5	20
31	Phenol	2%	60	0.33	3.5	20
32	Di-nitro-phenol	1%	60	0.0	3.7	16
33	Paradichlorobenzene	20%	30	0.0	3.7	16
34	Paradichlorobenzene	10%	30	0.0	3.7	16
35	Sodium-ortho-phenyl-phenylate	2%	60	0.67	3.7	16
36	Phenyl-iso-thio-cyanate	1%	60	0.0	3.8	14
37	Tri-phenyl-arsine	1%	110	0.0	3.9	11
38	Ortho-cresol	2%	60	0.33	4.0	9
39	Di-chloro-nitro-benzene	1%	50	0.40	4.0	9
40	Paradichlorobenzene	1%	60	0.0	4.0	9

39	benzene	1%	30	0.10	4.0	9
40	Paradichlorobenzene	1%	60	0.0	4.0	9
41	Para-para-dichloro-di-phenol	1%	60	0.50	4.0	9
42	2-Chloro-6-phenyl phenol	2%	90	0.56	4.1	7
43	3-5 Di-nitro-ortho-cresol	1%	60	0.0	4.2	5
44	1-2-4 Tri-chloro-benzene	1%	60	0.0	4.3	2
45	Ortho-cyclo-hexyl-phenol	2%	30	0.0	4.3	2
46	Nitro-benzene	2%	30	0.0	4.3	2
47	Sodium-chloro-ortho-cyclo-hexyl phenate	2%	90	0.11	4.3	2
48	Phenyl-alpha-naphthylamine	1%	60	0.17	4.3	2
49	Dimethyl amino-benzyl aldehyde	2%	30	0.67	4.3	2
50	Ortho-phenyl-phenol	10%	30	0.0	4.3	2
51	White Oil- Control	None	1300	0.19	4.4	0
52	Phenacyl chloride	2%	40	0.5	4.5	-2
53	Tetra-chloro-benzene	5%	60	0.17	4.7	-7
54	Di-phenyl-amino-arsine	2%	30	0.0	4.7	-7
55	1-3-5 Tri-nitro-benzene	1%	60	0.0	4.8	-9
56	Cumidine	2%	40	0.0	4.8	-9
57	2-4 Di-chloro-phenol	1%	60	0.17	4.8	-9
58	Para-nitro-aniline	1%	50	0.0	5.0	-14
59	Beta-chloro-ethyl-para-toluene sulfonate	1%	60	0.48	5.0	-14
60	Para-di-iodo-benzene	1%	40	0.25	5.0	-14
61	White Oil Saturated with tannic acid	Sat.	30	0.0	5.2	-18
62	2-4 Di-nitro-chloro-benzene	1%	60	0.17	5.2	-18
	2-4 Di-nitro-bromo-					

56	Cumidine	2%	40	0.0	4.8	-9
57	2-4 Di-chloro-phenol	1%	60	0.17	4.8	-9
58	Para-nitro-aniline	1%	50	0.0	5.0	-14
59	Beta-chloro-ethyl-para-toluene sulfonate	1%	60	0.48	5.0	-14
60	Para-di-iodo-benzene	1%	40	0.25	5.0	-14
61	White Oil Saturated with tannic acid	Sat.	30	0.0	5.2	-18
62	2-4 Di-nitro-chloro-benzene	1%	60	0.17	5.2	-18
63	2-4 Di-nitro-bromo-benzene	2%	50	0.40	5.4	-23
64	Bromo-benzo-nitrile	1%	60	0.33	5.7	-30
65	Para-nitro-bromo-benzene	2%	60	0.17	5.8	-32
66	Para-toluidene	1%	30	0.0	6.3	-43

SUMMARY

Item No.	No. of Mixtures Tested	Materials Tested	Percentage of Material Added	No. Larvae	Ave. Ent.per Apple	Average Percentage of Control
1	10	Hydroxyl or methyl groups or both combined with benzene ring	2-10	530	3.2	27
2	3	Iodine combined with benzene ring	1-10	100	3.3	25
3	8	Bromine combined with benzene ring	1-20	480	3.6	18
4	66	Benzene ring mixtures	1-20	3530	3.6	18
5	23	Chlorine combined with benzene ring	1-20	1300	3.9	11
6	10	Amino group combined with benzene ring	1-2	440	4.0	9
7	10	Nitro group combined with benzene ring	1-2	720	4.1	7

In Table XVII are listed the mixtures that were tested that contained the naphthalene ring.

1-3-8 Tri-nitro-naphthalene, (Item 1, Table XVII) gave the best control.

Nitro groups and iodine increased the toxicity of naphthalene in the compounds tested. Chlorine did not in general increase the toxicity. Amino groups except in alpha-naphthylamine and bromine decreased the toxicity of naphthalene in the mixtures tested.

Table XVII

TOXICITY TO CODLING MOTH LARVAE OF UNEMULSIFIED WHITE OIL IMPREGNATED WITH COMPOUNDS CONTAINING THE NAPHTHALENE GROUP

Item No.	Material Added to White Oil	Amount Added	No. Larvae Used	Average per Apple Stings	Average per Apple Entries	Percentage of Control of Entries
1	1-3-8 Tri-nitro-naphthalene	1%	30	0.33	1.3	71
2	Naphthalene	10%	30	0.0	1.7	61
3	Alpha naphthylamine	2%	30	0.0	2.0	55
4	Beta-iodo-naph-thalene	2%	30	0.0	2.0	55
5	Beta-chloro-naphthalene	2%	60	0.33	2.3	48
6	Beta-iodo-naphthalene	20%	30	0.0	2.7	39
7	Alpha-nitro-naphthalene	2%	60	0.33	2.8	36
8	Mono-chloro-naphthalene	2%	60	0.17	3.0	32
9	1-nitro-2-naphthol	2%	90	0.33	3.0	25
10	Naphthalene	2%	90	0.0	3.4	23
11	Tri-hexa-chloro-naphthalene	1%	50	0.0	3.6	18
12	Beta-bromo-naphthalene	2%	60	0.33	4.0	9
13	Beta naphthol	1%	70	0.14	4.0	9
14	Beta-iodo-naphthalene	1%	40	0.0	4.2	5
15	Phenyl-alpha-naphthylamine	1%	60	0.17	4.3	2
16	Beta-bromo-naphthalene	20%	30	0.0	4.3	2
17	Di-nitro-naphthalene	1%	60	0.50	4.3	2
18	Beta-chloro-naphthalene	20%	30	0.0	4.3	2

10	Naphthalene	2%	90	0.0	3.4	23
11	Tri-hexa-chloro-naphthalene	1%	50	0.0	3.6	18
12	Beta-bromo-naphthalene	2%	60	0.33	4.0	9
13	Beta naphthol	1%	70	0.14	4.0	9
14	Beta-iodo-naphthalene	1%	40	0.0	4.2	5
15	Phenyl-alpha-naphthylamine	1%	60	0.17	4.3	2
16	Beta-bromo-naphthalene	20%	30	0.0	4.3	2
17	Di-nitro-naphthalene	1%	60	0.50	4.3	2
18	Beta-chloro-naphthalene	20%	30	0.0	4.3	2
19	White Oil- Control	None	1300	0.19	4.4	0
20	Di-bromo-naphthalene	1%	60	0.17	4.5	-2
21	Bromo-beta-naphthol	1%	60	0.17	5.0	-14
22	Beta-naphthylamine	2%	30	0.0	5.7	-30

SUMMARY

Item No.	No. of Mixtures Tested	Material Tested	Percentage of Material Added	No. Larvae	Ave. Ent.per Apple	Average Percentage of Control
1	4	Nitro groups combined with naphthalene	1-2	240	2.9	34
2	3	Beta-iodo-naphthalene	1-20	100	3.0	32
3	4	Chlorine combined with naphthalene	1-20	200	3.3	25
4	21	Naphthalene Mixtures	1-20	1060	3.4	23
5	3	Amino groups combined with naphthalene	1-2	120	4.0	9
6	4	Bromine combined with naphthalene	1-20	210	4.4	0

In Table XVIII are listed the two anthracene mixtures that were tested.

When chlorine was combined with anthracene an increase in toxicity was observed. The toxicity of both the anthracene mixtures was low.

Table XVIII

TOXICITY OF UNEMULSIFIED WHITE OIL IMPREGNATED WITH ANTHRACENE TO CODLING MOTH LARVAE

Item No.	Material Added to White Oil	Amount Added	No. Larvae Used	Average per Apple		Percentage of Control of Entries
				Stings	Entries	
1	9-10 Di-chloro-anthracene	1%	50	0.0	3.6	18
2	White Oil- Control	None	1300	0.19	4.4	0
3	Anthracene	1%	60	0.17	4.7	-7

In Table XIX are listed the cyanogen and thio-cyanate compounds that were tested.

Copper cyanide, (Item 1, Table XIX) gave the best control.

Allyl-iso-thio-cyanate which is extremely irritating gave a fair degree of control.

Most of the compounds tested were comparatively insoluble in the oil.

Table XIX

TOXICITY TO CODLING MOTH LARVAE OF UNEMULSIFIED WHITE OIL IMPREGNATED WITH CYANOGEN AND THIO-CYANATE COMPOUNDS

Item No.	Material Added to White Oil	Amount Added	No. Larvae Used	Average per Apple Stings	Average per Apple Entries	Percentage of Control of Entries
1	Copper cyanide	2%	60	0.0	1.8	59
2	Allyl-iso-thio-cyanate	1%	60	0.33	2.3	48
3	Copper sulfocyanide	2%	60	0.0	3.0	32
4	Sodium cyanide	1%	50	0.20	3.4	23
5	Sodium sulfocyanate	1%	60	0.0	3.7	16
6	Phenyl-iso-thio-cyanate	1%	60	0.0	3.8	14
7	Cyanamide	2%	30	0.0	4.3	2
8	White Oil- Control	None	1300	0.19	4.4	0
9	Cyanogen bromide	1%	60	0.0	5.3	- 20
10	p-bromo-benzo-nitrile	1%	60	0.33	5.7	- 30

SUMMARY

Item No.	No. of Mixtures Tested	Material Tested	Percentage of Material Added	No. Larvae	Ave. Ent. per Apple	Average Percentage of Control
1	9	Cyanogen and Thiocyanate Mixtures	1-2	500	3.6	18

In Table XX are listed the aliphatic carbon mixtures that were tested.

Copper oleate, (Item 1, Table XX) was the most toxic of the mixtures that contained aliphatic carbon groups.

Menthol and cetyl alcohol, (Items 13 and 26, Table XX) which were the only hydrocarbons tested in this group, were ineffective.

Table XX

TOXICITY TO CODLING MOTH LARVAE OF UNEMULSIFIED WHITE OIL IMPREGNATED WITH ALIPHATIC CARBON COMPOUNDS

Item No.	Material Added to White Oil	Amount Added	No. Larvae Used	Average per Apple		Percentage of Control of Entries
				Stings	Entries	
1	Copper oleate	2%	150	0.27	1.8	59
2	Allyl-iso-thio-cyanate	1%	60	0.33	2.3	48
3	Cetyl-arsenite	1%	20	0.0	2.3	43
4	Carbon-tetra-chloride	1%	20	1.0	2.5	43
5	Barium stearate	1%	30	0.0	2.7	39
6	Tetra-chloro-ethylene	20%	30	0.0	2.7	39
7	Copper oleate (Excess acid)	5%	60	0.8	2.8	36
8	Stearic acid Arsenious oxide	2% 1%	60	0.5	3.0	32
9	Barium oleate	1%	50	0.0	3.2	27
10	Thallous malonate	2%	60	0.33	3.3	25
11	Lamp black Sodium arsenite	2% 1%	30	0.0	3.3	25
12	Copper oleate	5%	110	0.18	3.5	20
13	Menthol	2%	50	0.2	3.6	18
14	Bromo-picrin	1%	50	0.0	4.2	5
15	Chloro-picrin	1%	60	0.83	4.2	5
16	1 part lamp black, 5 parts arsenious oxide	3%	30	0.33	4.3	2
17	Bromo-form	1%	60	0.33	4.3	2
18	Tetra-chloro-ethylene	1%	60	0.17	4.3	2

11	Lamp black Sodium arsenite	2% 1%	30	0.0	3.3	25
12	Copper oleate	5%	110	0.18	3.5	20
13	Menthol	2%	50	0.2	3.6	18
14	Bromo-picrin	1%	50	0.0	4.2	5
15	Chloro-picrin	1%	60	0.83	4.2	5
16	1 part lamp black, 5 parts arsenious oxide	3%	30	0.33	4.3	2
17	Bromo-form	1%	60	0.33	4.3	2
18	Tetra-chloro-ethylene	1%	60	0.17	4.3	2
19	White Oil- Control	None	1300	0.19	4.4	0
20	Chloro-acetone	1%	60	0.0	4.8	-9
21	Lamp black Sodium fluoride	2% 1%	20	0.25	5.0	-14
22	Cetyl fluoride	2%	30	0.0	5.0	-14
23	Carbon disulfide	2%	30	0.0	5.0	-14
24	Iodoform	1%	40	0.25	5.0	-14
25	Cyanogen bromide	1%	60	0.0	5.3	-20
26	Cetyl alcohol	2%	60	0.17	5.5	-25

SUMMARY

Item No.	No. of Mixtures Tested	Materials Tested	Percentage of Material Added	No. Larvae	Ave. Ent. per Apple	Average Percentage of Control
1	5	Chlorine mixtures	1-20	230	3.7	16
2	25	Aliphatic carbon mixtures	1-20	1290	3.8	14
3	3	Bromine mixtures	1	170	4.6	-5

In Table XXI are listed the results of the tests of mixtures containing the hydroxyl group.

Methyl salicylate, (Item 1, Table XXI) gave the highest percentage of control in this series of tests.

Bromine combined with the hydroxyl group showed the highest toxicity of any group of mixtures in this table. This is the only combination of bromine that showed any appreciable toxicity. This is probably due to the toxicity of 3-5 di-bromo-ortho-cresol which was the most toxic bromine compound tested.

Nitro groups and chlorine combined with the hydroxyl group did not show significant toxicity in the compounds tested.

Table XXI

TOXICITY TO CODLING MOTH LARVAE OF UNEMULSIFIED WHITE OIL IMPREGNATED WITH COMPOUNDS CONTAINING THE HYDROXYL GROUP

Item No.	Material Added to White Oil	Amount Added	No. Larvae Used	Average per Apple Stings	Average per Apple Entries	Percentage of Control of Entries
1	Methyl salicylate	2%	30	0.0	1.3	71
2	3-5 Di-bromo-ortho-cresol	1%	30	0.67	2.3	48
3	3-5 Di-bromo-ortho-cresol	5%	70	0.0	2.3	48
4	3-5 Di-bromo-ortho-cresol	2%	120	0.17	2.5	43
5	Thymol	2%	50	0.2	2.6	41
6	2-4 Di-chloro-6-phenyl phenol	2%	30	0.0	2.7	39
7	1-Nitro-2-Naphthol	2%	90	0.33	3.3	25
8	Ortho-phenol-phenol	2%	120	0.0	3.4	23
9	Phenol	2%	60	0.33	3.5	20
10	Tri-nitro-resorcinol	1%	60	0.0	3.5	20
11	Menthol	2%	50	0.2	3.6	18
12	Di-nitro-phenol	1%	60	0.0	3.7	16
13	Para-para-dichloro-di-phenol	1%	60	0.5	4.0	9
14	Ortho-cresol	2%	60	0.33	4.0	9
15	Beta Naphthol	1%	70	0.14	4.0	9
16	2-Chloro-6-phenyl-phenol	2%	90	0.56	4.1	7
17	3-5 Di-nitro-ortho-cresol	1%	60	0.0	4.2	5
18	Ortho-cyclo-hexyl-phenol	2%	30	0.0	4.3	2

11	Menthol	2%	50	0.2	3.6	18
12	Di-nitro-phenol	1%	60	0.0	3.7	16
13	Para-para-dichloro-di-phenol	1%	60	0.5	4.0	9
14	Ortho-cresol	2%	60	0.33	4.0	9
15	Beta Naphthol	1%	70	0.14	4.0	9
16	2-Chloro-6-phenyl-phenol	2%	90	0.56	4.1	7
17	3-5 Di-nitro-ortho-cresol	1%	60	0.0	4.2	5
18	Ortho-cyclo-hexyl-phenol	2%	30	0.0	4.3	2
19	Ortho-phenyl-phenol	10%	30	0.0	4.3	2
20	White Oil- Control	None	1300	0.19	4.4	0
21	2-4 Di-chloro-phenol	1%	60	0.17	4.8	-9
22	Bromo-beta-naphthol	1%	60	0.17	5.0	-14
23	Cetyl alcohol	2%	60	0.17	5.5	-25

SUMMARY

Item No.	No. of Mixtures Tested	Materials Tested	Percentage of Material Added	No. Larvae	Ave. Ent. per Apple	Average Percentage of Control
1	4	Hydroxyl bromine mixtures	1-5	280	3.0	32
2	9	Hydroxyl aromatic mixtures	1-10	450	3.3	25
3	22	Hydroxyl mixtures	1-10	1350	3.5	20
4	4	Hydroxyl nitro-mixtures	1-2	270	3.7	16
5	4	Hydroxyl chlorine mixtures	1-2	240	3.9	11
6	2	Hydroxyl aliphatic mixtures	2	110	4.5	-2

In Table XXII comparison of the toxicity of bromine, chlorine and iodine, both free and combined, is drawn. Section 1 summarizes the results obtained with bromine and 3 compounds containing bromine. Section 2 summarizes the results obtained with chlorine in the same compounds as were used in Section 1 but with chlorine substituted for bromine. Section 3 summarizes the results obtained with iodine and the same three compounds except that iodine was substituted for bromine.

Additional comparisons: Items 7, 8 and 9, Table XXII give some further comparisons of these compounds but the iodine compounds were not available in Items 8 and 9 and in Item 7 an excessive amount of chloroform was added.

The data summarized in Table XXII show that of the compounds tested and in the elemental form when used with White Oil, iodine is the most toxic of these three halogens to codling moth larvae. Chlorine gave fewer entries per apple than bromine.

Bromoform, chloroform and iodoform, (Item 7, Table XXII) show a marked lack of toxicity to codling moth larvae 24 hours after they were applied to the apples.

Table XXII

A COMPARISON OF THE TOXICITY TO CODLING MOTH LARVAE OF BROMINE, CHLORINE AND IODINE MIXED WITH UNEMULSIFIED WHITE OIL

Item No.	Compound Tested*	Section 1 BROMINE Amt. Used	Section 1 BROMINE Ent. per Apple	Section 2 CHLORINE Amt. Used	Section 2 CHLORINE Ent. per Apple	Section 3 IODINE Amt. Used	Section 3 IODINE Ent. per Apple
1	Bromine	1%	4.2	2%	4.2	1%	2.6
2	Beta-bromo-naphthalene	2%	4.0	2%	2.3	2%	2.0
3	Beta-bromo-naphthalene	20%	4.3	20%	4.3	20%	2.7
4	Para-nitro-bromo-benzene	2%	5.8	2%	2.8	2%	2.3
5	Para-di-bromo-benzene	1%	3.2	1%	4.0	1%	5.0
6	Para-di-bromo-benzene	20%	1.7	20%	3.7	10%	2.7
	AVERAGE		3.9		3.5		2.9

* Chlorine and Iodine are substituted for Bromine in Sections 2 and 3.

Additional Comparisons

7	Bromo-form	1%	4.3	10%	4.3	1%	5.0
8	Bromo-picrin	1%	4.2	1%	4.2		
9	2-4 Di-nitro-bromo-benzene	1%	5.4	1%	5.2		
10	White Oil- Control		4.4				

Table XXIII is a summary of the average percentage of control of entries obtained in each of the groups of compounds investigated. The number of compounds making up these groups was limited (2 to 66 mixtures were used), but in general the ranking of the groups indicates the varying toxicity to codling moth larvae of these compounds when they were mixed with unemulsified White Oil.

Nicotine, one of the plant extract group, (Item 1, Table XXIII) was the most effective of the materials studied.

Copper mixtures, (Item 2, Table XXIII) showed marked toxicity to codling moth larvae. None of the mixtures that contained copper showed less than 20 per cent control of entries.

The two barium mixtures, (Item 3, Table XXIII) possessed marked toxicity at 1 per cent concentration.

Nitro-naphthalene (Item 4, Table XXIII) possessed marked toxicity.

Iodine mixtures (Item 8, Table XXIII) ranked 11 per cent above chlorine mixtures (Item 18, Table XXIII), and chlorine mixtures ranked 7 per cent more effective than bromine mixtures. Iodine, para-chloro-aniline and beta-chloro-naphthalene at 2 per cent and 3-5 di-bromo-ortho-cresol at 1 per cent were the mixtures containing these three elements that gave the best control at concentrations

of 2 per cent or less.

Naphthalene mixtures (Item 12, Table XXIII) ranked slightly above benzene mixtures (Item 16, Table XXIII), and 16 per cent above anthracene mixtures (Item 31, Table XXIII).

The addition of iodine to naphthalene (Item 5, Table XXIII) increased its effectiveness over the average of all naphthalene mixtures (Item 12, Table XXIII). Chlorine combined with naphthalene (Item 10, Table XXIII) shows a slight improvement. Bromo-naphthalene mixtures (Item 33, Table XXIII) markedly decreased the toxicity below the average of all the naphthalene mixtures.

Aromatic compound mixtures (Item 13, Table XXIII) were more toxic than aliphatic compound mixtures (Item 22, Table XXIII).

Cyanogen and thio-cyanate mixtures (Item 15, Table XXIII) showed only slight toxicity.

Amino mixtures were of a low order of toxicity as a group but a-naphthylamine possessed marked toxicity.

Of the 36 groups of mixtures investigated 32 possessed some toxicity to codling moth larvae. All the groups giving a negative percentage of control were mixtures that contained aliphatic carbon structure.

Table XXIII

UNEMULSIFIED IMPREGNATED WHITE OIL AS A LARVICIDE

FOR CODLING MOTH

Item No.	Table No.	No. of Mixtures	Material Added	Percentage of Materials Added	No. Larvae Used	Ave. Ent. per Apple	Ave. Percentage of Control of Entries
1	XV	16	Plant Extracts	1-25	1060	2.0	55
2	XIV	5	Copper Mixtures	2-15	440	2.6	41
3	XIV	2	Barium Salts	1	80	2.9	34
4	XVII	4	Nitro-Naphthalenes	1-2	240	2.9	34
5	XVII	3	Beta-iodo-naphthalene	1-20	100	3.0	32
6	XXI	4	Hydroxyl Bromines	1-5	280	3.0	32
7	XVI	10	Hydroxyl or methyl derivatives of benzene	2-10	530	3.2	27
8	X	9	Iodine Mixtures	1-2	320	3.2	27
9	XVI	3	Iodo-Benzenes	1-10	100	3.3	25
10	XVII	4	Chloro-Naphthalenes	1-20	200	3.3	25
11	XXI	9	Hydroxyl Aromatics	1-10	450	3.3	25
12	XVII	21	Naphthalenes	1-20	1060	3.4	23
13	VIII	15	Aromatic Carbon Compounds	1-10	840	3.5	20
14	XXI	23	Hydroxyl Compounds	1-10	1350	3.5	20
15	XIX	9	Cyanogen & Thio-Cyanates	1-2	500	3.6	18
16	XVI	66	Benzene Derivatives	1-20	3530	3.6	18
17	XVI	8	Bromo-Benzenes	1-20	480	3.6	18

15	XIX	9	Cyanogen & Thio-Cyanates	1-2	500	3.6	18
16	XVI	66	Benzene Derivatives	1-20	3530	3.6	18
17	XVI	8	Bromo-Benzenes	1-20	480	3.6	18
18	XII	34	Chlorine Compounds	1-20	1830	3.7	16
19	XXI	4	Hydroxyl-Nitro Mixtures	1-2	270	3.7	16
20	XX	5	Chloro-Aliphatic Carbon Compounds	1-20	230	3.7	16
21	IX	20	Nitro-Compounds	1-2	1130	3.8	14
22	XX	25	Aliphatic Carbon Compounds	1-20	1290	3.8	14
23	XXI	4	Hydroxyl Chlorine Compounds	1-2	240	3.9	11
24	XIV	8	Arsenicals	1-2.5	400	3.9	11
25	XIII	12	Amino Compounds	1-2	480	3.9	11
26	XVI	23	Chloro-Benzenes	1-20	1300	3.9	11
27	XI	16	Bromine Compounds	1-20	910	4.0	9
28	XVII	3	Amino-Naphthalenes	1-2	120	4.0	9
29	XVI	10	Amino-Benzenes	1-2	440	4.0	9
30	XVI	10	Nitro-Benzenes	1-2	720	4.1	7
31	XVIII	2	Anthracenes	1	110	4.1	7
32	XIV	4	Ellpriane Compounds	2	140	4.1	7
33	XVII	4	Bromo-Naphthalenes	1-20	210	4.4	0
34			White Oil- Control		1300	4.4	0
35	VIII	2	Aliphatic Carbon Compounds	2	110	4.5	-2
36	XXI	2	Hydroxyl Aliphatic Carbon Compounds	2	110	4.5	-2
37	XX	3	Bromo-Aliphatic Compounds	1	170	4.6	-5

DISCUSSION

The unemulsified oil applied to the apples spread over the surface in a uniform film and did not collect in drops as it does when applied as summer oil emulsion. This spreading of the material into a thin film gave a critical test of the permanency of toxicity of the materials added to the oil. Volatile materials would escape from this thin film in a short time. Chemically active substances which would combine with the skin of the apple would have an ample period for most reactions to go to completion during the 24 hours that elapsed between the time the material was applied and when the larvae were placed on the apples. Oxidation by atmospheric oxygen may have taken place in many instances. As the apples were stored in a greenhouse any compounds that would be decomposed by light other than ultra violet light were probably destroyed before the larvae were placed on the apples. An apparent loss of toxicity may have resulted from some of the materials that were toxic in aqueous solution being enveloped in a film of oil which inhibited their toxic action.

No doubt all these factors reduced or eliminated entirely the toxic action to codling moth larvae of many of the mixtures that were tested. Some of the materials probably would have been toxic had they been applied directly to the

larvae. However, this is one of the most important points in the development of an insecticide for the control of codling moth larvae. The material must be of such a nature that it will remain on the apples in a form toxic to the larvae, in spite of rain, sunlight, temperature changes, oxygen, carbon dioxide, nitrogen, or other gases that may be present in the atmosphere and any plant material that may reach the surface of the fruit or foliage.

The rapid growth made by the apples during periods of codling moth activity makes it difficult to maintain a continuous film of insecticide covering the fruit. Therefore, the material should be sufficiently toxic to kill the larvae by contact or should be attractive so that the larvae will feed upon it before they begin to make an entry hole into the apple.

The chemical structure and other constants of the materials used in these tests are given as a convenient means of describing them. The chemical description of materials is so comprehensive that it serves as a good foundation for any studies treating a large number of widely different materials. With this fact in mind the author selected chemical structure and other constants of a material usually given in chemical descriptions as a convenient basis and starting point upon

which to build some knowledge of the toxic properties of various materials to codling moth larvae. The classification of materials by their chemical reactions does not imply that any element or radical in a compound is responsible by its chemical action for the toxicity possessed by the compound. The change in solubility, melting point, molecular structure, molecular orientation in any given medium, or any other change which an element or a radical may produce in a compound in addition to its chemical activity may result in an increase or decrease in toxicity.

SUMMARY

Over 100 chemical compounds were mixed with White Oil, a refined petroleum oil, and tested for their toxicity to newly hatched codling moth larvae (Carpocapsa pomonella Linne).

Of the mixtures tested, nicotine, nicotine sulfate, 1-3-8 tri-nitro-naphthalene, methyl salicylate, copper cyanide, copper oleate, a-naphthylamine and iodine were the most toxic at concentrations of 2 per cent or less in White Oil. Of these materials, nicotine and nicotine sulfate mixtures were the only ones that gave more than 71 per cent control of entries.

Thirty-six series of compounds were studied. Plant extract mixtures were the most toxic. Nicotine was the most toxic material tested in this series.

The copper mixtures tested possessed marked toxicity to the larvae. Copper cyanide was the most toxic material.

Barium, nitro-naphthalene and hydroxyl bromine mixtures and beta-iodo-naphthalene ranked next to copper mixtures in toxicity. Barium stearate was the most toxic barium compound tested. 3-5 Di-bromo-ortho-cresol was the most toxic at low concentrations of the bromine compounds.

Iodine, chlorine and bromine and some of their derivatives ranked in the order listed in toxicity to codling moth larvae in this series of tests.

Derivatives of naphthalene and naphthalene mixtures were slightly more toxic than derivatives of benzene and benzene mixtures in general.

Anthracene and 9-10 di-chloro-anthracene were practically non-toxic to codling moth larvae.

Aromatic compounds were more toxic than aliphatic compounds.

Cetyl arsenite was more toxic than the arsines or inorganic arsenic mixtures that were tested.

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